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Investigations in Details of Bridge Design.

Although the design of pin-connected bridges has been constantly advancing ever since the introduction of that type of construction, there is much yet to be learned concerning laying out details. This is admirably illustrated by the paper entitled "New Facts About Eye-Bars," by Theodore Cooper, presented before the American Society of Civil Engineers last week, an abstract of which appeared in this journal on Feb. 10. This paper contains a simple direct statement of certain facts about eye-bars disclosed by Mr. Cooper's investigations in connection with the design of the 1,800-ft. span Quebec cantilever bridge, now in process of construction.

In the consideration of the large 15-in. steel eye-bars required in this construction, Mr. Cooper has made a most interesting and fruitful research regarding the effect of stresses well below the elastic limit in the body of the bar on the eye-bar head. In the Quebec bridge the working stress in the main eye-bars is 21,000 lb. per square inch. Inasmuch as the pin cannot fit with mathematical exactness the pin-hole in the eye-bar, obviously any stress in the body of the bar, will distort to a corresponding degree the eye-bar head, giving an elongated or slightly pear shape to the pin hole. There is nothing new in this stress effect. It has been recognized for many years that an eye-bar under loads not exceeding ordinary working stresses will retain permanent, though exceedingly small, distortions of its head, although investigations connected with this particular detail have never been made so fully nor with so much care as characterized Mr. Cooper's work.

These considerations bring up again, at least to those engineers who had to do with the early days of pin-connected bridge building in this country, the whole question of design of the eye-bar head. Probably the most full, though approximate, analysis of stresses in the eye-bar head ever made, appeared in the "Transactions" of the American Society of Civil Engineers over thirty-one years ago, and it is rather interesting to observe that Mr. Cooper's investigations furnish experimental confirmation of some of the general stress conditions set forth in the early analysis. He observes with much force that the actual distortion of the eye-bar head under working loads and its effect upon the distribution of stresses in the different members of a group of eye-bars, are practically never recognized. This is not saying that no allowance is ever made for the distortion corresponding to a certain amount of play or lost motion at the pin joint, for frequently, perhaps generally, both in connection with camber computations and in computations determining the exact length of truss members, that play or distortion is recognized.

The effects of the compression of material at the bearing surfaces of pins are not confined to tension members only. The distortion caused by that compression is found also in the jaws or other similar details at the ends of compression members. The effect of the distortion of the eye-bar head by bending is absent at the ends of the compression members, but that may be partially offset at least by the bending in the bodies of these latter members. When one reflects that these various sources of distortion of members coupled together on a pin, must affect materially the distribution of stresses in those members, the importance of their full-size experimental investigation becomes easily apparent. This observation gains much force in cases like great bridge spans where pin lengths are correspondingly great, thus affording opportunity for the bending stresses in those pins to produce coresponding deflections, even with pins of large diameter. The degree of accuracy ordinarily atained in giving a bridge a desired camber shows conclusively that these distortions or strains are in general sufficiently provided for, but there still remains the question of redistribution of stresses in the members involved.

The effect of these eye-bar head distortions in deranging the assumed proper distribution of stresses in a bank or group of eye-bars is one of the most important topics touched upon by Mr. Cooper. He shows that even with the same grade of structural steel, and with the same width or depth of eye-bar, there may be considerable variation in the resulting lengths of bars between centers of pins, and consequently a corresponding derangement of the stresses which they carry. He indicates that it is advisable to employ a medium steel rather than a low or soft steel for eye-bars where this consideration or distortion of the eye-bar head is an important element in the structure. Inasmuch as the ordinary processes for the manufacture of eye-bar heads, combined with the subsequent process of annealing, may and usually do leave the heads of eye-bars, even of the same thickness, in somewhat different conditions as to hardness, it may readily be understood that quite different degrees of distortion may be found among a number of eye-bar heads coupled on the same pin. This variable distortion, however, may have an advantageous effect by adjusting permanent strains in the head where for any reason the eye-bars, as bored, may not have precisely the same length.

On the whole these investigations are rather assuring than otherwise, as showing that the long recognized but unmeasurable derangement of stresses among a number of parallel eye-bars coupled to the same pin is not of sufficient amount in good design to create any disturbing apprehensions. There is probably no perfect distribution of computed stresses among structural members meeting at any panel point in any structure whatever, whether the type of detail be of one kind or another, but it is satisfactory to ascertain with the advance of our actual knowledge of what goes on in structural members that the pin detail for great truss structures meets its exacting duties so well.

Public Works as Local Nurseries.

Governor Warfield, of Maryland, has turned down the registered voters' bill to compel contractors to employ only voters in building public works in that State. In a veto message written in the most plain language he has explained in detail the reasons for regarding any such attempt to control the labor market artificially as a menace to the public welfare. It is gratifying to be able to put on record such a decided refusal of a so-called labor demand by anybody holding a political office. The purpose of the bill was nominally to protect local labor, but its terms were so drawn that it rendered contracting for public work in Maryland impossible except for those who stood in with the self-appointed heads of the labor organizations. These labor chiefs would be in a position to blackmail contractors as they saw fit, under the terms of the proposed legislation, and the taxpayers would have to pay out excessive sums for their public buildings, roads, sewers, water works and other undertakings. As this bill was the most pronounced attempt ever made to rob the taxpayer in the name of the local laborer, it has attracted attention throughout the country and its veto deserves similar publicity.

Although this particular bill was so bad, it must be acknowledged that spending money for public works among local workmen and dealers deserves a good deal of sympathy, as a general proposition. The taxes paid to furnish money for the works come from local people, and if the expenditures for materials and labor are made to local parties the money will return in a large measure to those from whom it came originally. The trouble with the plan is that unless outside competition is admitted, the public works will shortly become the private pasturage for a few local political goats, growing fat at the expense of everybody else. Competition must be permitted in order to prevent this condition, but the existence of competition does not mean that local interests will not be fully protected, both in the purchase of supplies and in hiring labor. For example, there has recently been completed in Harrisburg, Pa., a system of water purification works which were constructed under difficult conditions. The engineer, Mr. James H. Fuertes, spent an unusual amount of attention on his estimates in consequence and the amount he stated as the reasonable cost of the works was unquestionably a fair one. When the bids for the work were opened, all but one of them were very high, unless memory is at fault, but that one, from an outside bidder, was in close agreement with the engineer's figures. Had the contract been let to local parties the plant would have cost more instead of less than the engineer's estimate, while it is not likely that more than a very few individuals in the city would have been benefited by such an award.

Few people appreciate that this whole idea of making public contracts a local nursery is based on mistaken views of what a contractor actually does who comes into a city from outside. He first establishes credit at a local bank and then with local tradesmen, after which he investigates the condition of the local labor market. Just so far as it is practicable for him to rely on local resources he will do so, even at some additional expense to himself, because, by establishing a good business reputation in the vicinity in this way, he can secure help promptly in meeting the unforeseen troubles that often arise and against which he can only provide by following such a course. If there is a local dealer who can supply materials promptly at a reasonable price the contractor will arrange to purchase them through him, while he will secure all his labor from the vicinity if possible, because by so doing he will be free from the annoyance of running a camp and bringing men to the work from wherever he can find them. In fact, one of the best patrons of local shops and local labor is an outside contractor, and it is common knowledge that he is often willing to pay even better prices than the local contractors.

The policy of restricting bids for supplies for public works to local agents is one with nothing whatever in its favor and much against it. In this case the materials are not made in the city and nobody is favored by the policy of restricting the competition for them. A short time ago a New England city bought a large quantity of paving brick, a material that was not produced anywhere near it. Through the lack of publicity given to the proposed purchase, for some reason with which this journal is not acquainted, few of the large manufacturers knew of the letting until it was too late for bids to be prepared, and as a result the city will pay to an outside industry a sum much in excess of what should be the ruling price. This unusually high price, which must make the local authorities disgusted when they appreciate its magnitude, is the only gratifying incident in the whole affair, for it should teach the importance of permitting free competition.

The Business View of Water Waste.

A few weeks ago attention was called to the importance of the waste of water in Philadelphia by the chief of the Bureau of Filtration of that city, who pointed out that the excessive waste would make it necessary to spend large sums for the construction of works for purifying the local supply, which would be saved could the waste be restricted. This week the Society for the Prevention of Crime, a reform organization in New York City, of which Dr. Parkhurst is the head, has made public some information concerning the waste of water in the Boroughs of Manhattan and the Bronx. In other cities the subject is now receiving attention, and for this reason it is well to point out what may be termed the business view of water waste. It is not a simple subject to discuss in detail, although its fundamental principle is of the most elementary character, being nothing more than the fact, acknowledged by every manager of water, gas and electric plants, that it is less expensive to permit a certain amount of waste than it is to prevent it. The difficulty of the problem lies in determining just what percentage of the waste it is expedient to check, and this difficulty may be appreciated when it is considered that the cost of supplying water is not the same in any two cities. It is manifestly as prejudicial to the economical conduct of a business to spend more money to prevent small wastes than the value of the product wasted, as it is to permit the waste of products which can be saved at a relatively small cost. The problem is one that is duplicated in ore reduction plants and in many lines of manufacturing, where the raw materials are of low cost and the product is of small unit value.

When the problem of water waste is examined in this way it will be evident why nothing but the most general statements can be made concerning it, unless the data of some one city are adopted for consideration. Where the water supply must be pumped and purified, or must be brought to the city through long lines of aqueducts supplied by reservoirs costing large sums, the expense of the water per million gallons will be much more than in cases where it is pumped from an inexhaustible source near the city and is of such a pure quality that it needs no purification. It will be recalled that Prof. Gardner S. Williams pointed out some years ago that in Detroit it was probably cheaper under the conditions that were then existing to put in new pumps than to spend money for a universal meter system. In the case of Philadelphia and Washington, on the other hand, it is safe to say that the prevention of waste ought to be undertaken at once, in order to avoid extensions of expensive works simply to provide filtered water which is wasted by a comparatively small proportion of the residents. In some other places, like Chicago, which are growing very fast and have to be extremely economical in public expenditures in order to keep within the debt limit, it is absolutely necessary to restrict waste in order to avoid enormous expenditures for pumping machinery. It is found by experience that the demand for water increases somewhat faster than the population, and a city growing as rapidly as Chicago is consequently called upon to spend very large sums on its water works even with careful restriction of waste. These differences in local conditions show that attempts to draw exact comparisons between the methods and results in one city and those in another are likely to prove so hopeless that the investigator will give them up in despair or else content himself with generalities likely to mislead people.

Another feature of water waste that is strictly a business one is the determination of the data for any investigation of the subject. Decisions concerning financial matters must be based on reasonably accurate information. In many cities the amount of water supplied to a city can only be ascertained by means of the pumping station records. These give the number of strokes of the pump and it is customary to multiply these strokes by the volume of the cylinder and consider the product the amount pumped, although the slip of the pump may render this measurement extremely inaccurate, sometimes being probably as much as 25 per cent. in excess of the amount actually delivered. Another source of serious error occurs in cities where house tanks are used and the distributing mains are hardly adequate to supply the daytime demand for water; in such cases there will be a considerable flow through the mains at night in order to fill the house tanks, and if the reason for this flow during hours when the natural consumption is trifling is not understood an investigator will be likely to report a considerable waste when the actual amount may be very small. These are but two of many sources of error rarely considered in popular discussions of water waste.

The prevention of waste is a subject of such importance and such complexity in its practical details that it is a matter of some regret to observe any tendency to make it anything but a business problem. For example, the Society for the Prevention of Crime has collected information which may or may not indicate important leakage of water from the reservoirs at Central Park and Jerome Ave. in New York, as well as from other sources. These statements concerning leakage all refer to amounts that are insignificant in comparison with the total legitimate consumption in the city. In any great city there will always be places where waste can be found by those hunting for it, and people noticing such places will accomplish much more good by bringing them to the attention of the local water department than by making them the subject for a public outcry. It should be understood that even in cities where the best theoretical methods are followed to restrict water waste, where the amount of water delivered is measured with reasonable accuracy, where all leakages in street mains are promptly stopped when detected, and practically all the service pipes are provided with a meter, the amount of water registered by the meters averages only about one-half of that pumped. It is on account of this experience in places which have adopted the theoretically best system of water works management, as well as on account of the results of the important investigations made in New York by Mr. Nicholas S. Hill, Jr., for the Board of Additional Water Supply, that a plea must be made for greater attention to the business aspects of waste prevention. It is far more complicated than any one can appreciate who has not become acquainted with the detailed experience in waste prevention of the superintendents of the water departments of numerous cities.

The Railroad Tracks on Eleventh Avenue, New York.

On Monday Governor Higgins signed a bill requiring the New York Central Railroad to remove its surface tracks on Eleventh Ave., New York. This bill was introduced by a State Senator elected from a New York City district for the express purpose of securing the passage of some such legislation if possible. The new act provides that the tracks may be placed in a subway or gives the city the right to condemn the company's rights on the surface of the street upon payment of adequate compensation. In a memorandum filed with the bill, the Governor makes the following comment: "The bill provides for proper compensation and due process of law, and while it imposes a heavy burden upon the railroad company by compelling it to construct a subway or leave the avenue entirely, it must be remembered that said company has for many years past enjoyed the use of a principal thoroughfare in derogation of the rights of the public and in a manner necessarily interfering with the legitimate use of the avenue as a highway and fraught with danger to life and limb. I am not seriously concerned with the engineering problems presented in the plan for a proposed subway. If such plan is impracticable, by reason of expense or other conditions, the company is not required to undertake impossibilities, but it may take its tracks out of the avenue, if it elects to do so, in which case it will receive compensation for all lawfully existing privileges which are thereby taken from it."

The case is a most interesting one, because it shows how railway facilities which were at one time eagerly welcomed may become very unpopular at a later time, not through any decline in their actual importance but through the change of conditions in other respects. The ordinance giving the company the right to occupy the street was passed in 1847, when much of the territory traversed was not built up at all, and other districts had but few buildings. Owing to the facilities for shipping which these tracks afford a number of lines of business have settled along the railroad, which is essential for them. On the other hand the growth of the city has made the presence of trains unpleasant to many people in the vicinity and a serious obstruction at times to teaming. If the tracks are removed, business amounting probably to many millions annually will be seriously affected, while a large number of people will be served more or less directly by the absence of freight trains from the streets. Just whether the presence of the tracks is more a benefit or a nuisance this journal cannot judge, for the question is one involving a great number of considerations.

It will be noticed that the act does not require the company to vacate the street, but only to leave the surface. As a matter of fact, however, a subway along the street would be a very costly undertaking because the ground water level in the vicinity is so high and the material in which the subway would have to be constructed is generally so porous, that the drainage and waterproofing problems would be almost insuperable. Moreover, the construction of spur tracks from such a subway into the two yards and the many private buildings along the route introduces a problem of equal difficulty. Consequently the act is in effect an order to the railroad to give up this freight service, for the subway which is permitted must be regarded as a very remote possibility.

It does not appear, nevertheless, that the matter is definitely settled yet, for the company has a year in which to reach an agreement with the city, before the latter can begin to condemn the rights. In this time some remedy which is practicable may be suggested. The company has repeatedly stated that it would welcome any practicable plan for taking its tracks from the street surface, for it is just as desirous of bettering the conditions on Eleventh Ave. as it is of removing grade crossings on all parts of its line. In the conferences which the company will hold with the Board of Rapid Transit Railroad Commissioners, which will represent the city in the matter, it is possible that some such plan will be devised. If one is not found, however, it might be suggested that the removal of the tracks may still be delayed many years. The railroad company, in justice to the many tradesmen and industries which depend on the tracks for their business existence in their present locations, will have to see that the act is legal. This will involve a resort to court proceedings which move slowly in New York State. While it is not considered likely that the company will fight the enforcement of the act, it will doubtless feel in duty bound to protect by all proper legal methods the interests of the shippers it has served for sixty years. The fact that the once welcome tracks, which led to the development of many important business enterprises in New York, are seriously in the way is not due to any fault or lack of care on the part of the company or its shippers, but to the inevitable growth of a great city. Consequently the enforcement of this act will result in such great financial losses to many of the people of the city that it will have to be carried out slowly and with proper regard to many more interests than those of the people who brought about the passage of the bill.

Notes and Comments.

A STATE POTABLE WATER COMMISSION has been organized by Governor Stokes of New Jersey for the purpose of making a careful study of the available sources of water supply and the methods of conserving and developing them. The commission consists of the State Riparian Commission and the State geologist, who have been officially in touch with public water supplies in the State for some years.

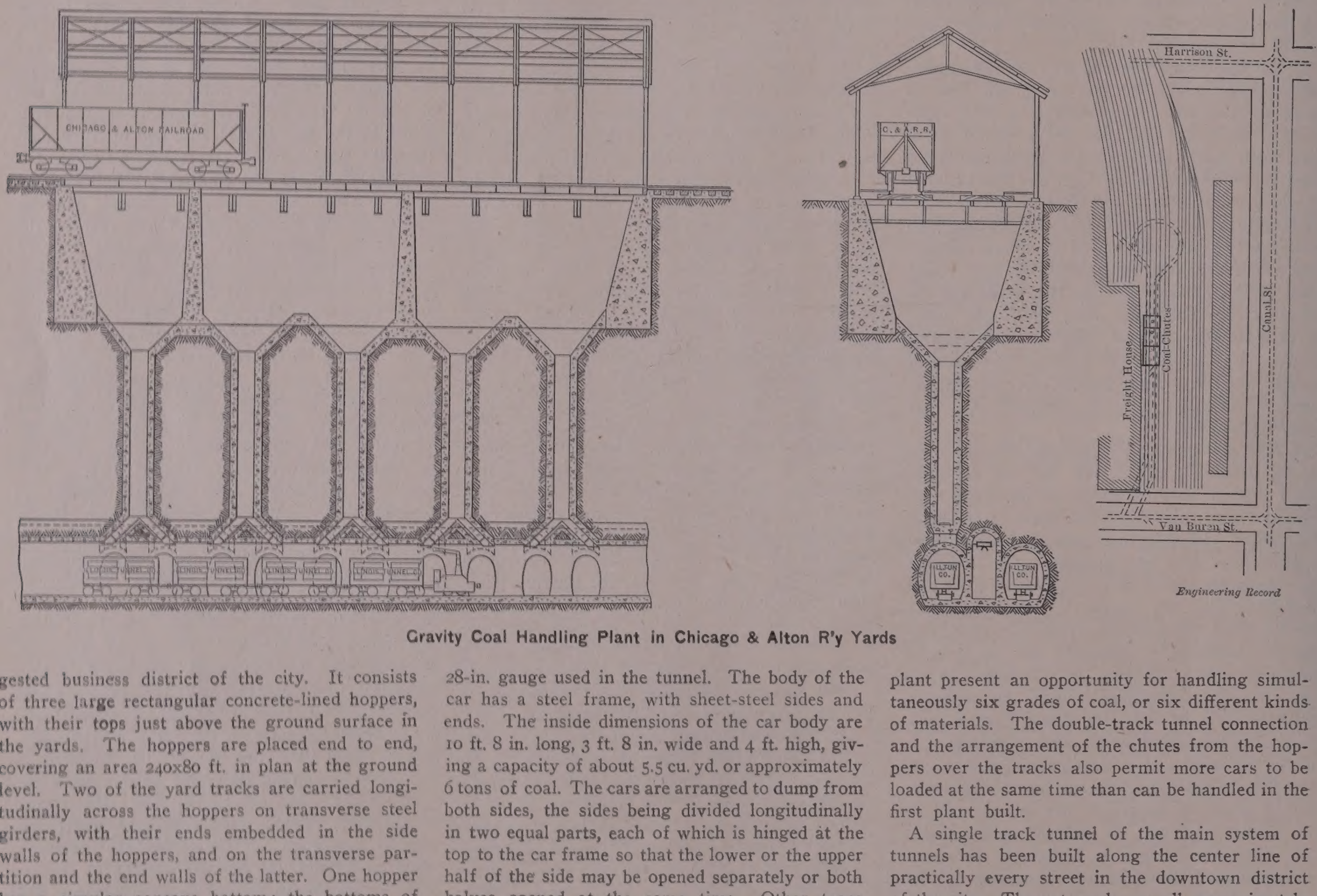
THE NIAGARA FALLS PROBLEM has reached such a stage that not only the American members of the International Waterways Commission but also President Roosevelt have called attention to it in very plain language. At the present time the falls receive more attention as a source of power than as one of the greatest natural beauties in North America. Just what value can be attached to them as one of the most picturesque places in the world can only be judged by comparison with the money that is spent for parks and other purposes. The land on which Central Park, New York, stands has been estimated at $225,000,000, a fact that affords some measure of comparison for estimating the value of Niagara Falls, which is, in a sense, a park for two nations rather than a single city. At present, power works on the American side of the river are authorized to take 26,700 cu. ft. from it, while those authorized on the Canadian side can take 34,200 cu. ft. per second. This makes a total of 60,900 cu. ft., which is 27 per cent. of the average discharge and 33 per cent. of the low water discharge over the falls. This amount is twice the discharge over the American falls at the average stage, and is about equal to to the discharge of Lake Superior. The American members of the Waterways Commission state that they cannot foretell what the effect on the falls of this diversion will be, but they believe that about one-sixth of it will be taken from the American falls and the remainder from those on the Canadian side. The fact that this diversion, when completed, may not seriously damage the beauty of the falls is not to be taken, they say, as an indication that any further diversion should be permitted. Accordingly they have recommended that authority be given to the Secretary of War to give permits for diverting 28,500 cu. ft. at the falls, at Chicago, and for the Erie canal, but that no further diversion be permitted for two years except for purposes of domestic supply and canal navigation. This prohibition is to remain in force for two years, and then, if Canada will pass a similar law prohibiting the diversion in the Dominion of more than 36,000 cu. ft., it is to become a permanent law. This recommendation has been submitted by the President to Congress, with a recommendation that it be acted upon favorably. Probably there has never been a more direct or important clash of the interests of industry and the desires of lovers of natural beauty. Although the rights of the companies which have already built works, as well as the franchises that have been granted, must be respected, it is safe to say that if the people of the two countries were once aroused to the result of much further diversion of the water above the falls they would not tolerate it.

THE SEWAGE PURIFICATION REPORT just issued by the Board of Public Service of Columbus is probably the most important American contribution to the literature of the subject since the report of the Massachusetts Board of Health on its investigations explaining the nature of intermittent filtration. The city was practically forced to make the investigations described in this report by the special conditions of its sewage disposal problem. It was long recognized that the sewage had to be purified before it was discharged into the river, but the problem was one of eliminating nuisances in the immediate vicinity of the city rather than preventing the pollution of the water supplies of lower riparian communities. There are no materials in the vicinity suitable for filters of the intermittent type. The first method of purification suggested was mechanical screening and double filtration through coke, but the recommendation for this method was coupled with one for the construction of an experimental plant where the process could be tested for a full year before the main works were put under contract. Nothing was done on this recommendation and two years later two projects were suggested, involving the use of septic tanks, but the State Board of Health refused to sanction them. A little later a third recommendation for septic tanks and intermittent filters was made coupled with the suggestion that the city should make experiments to ascertain the details of the process best adapted to the local conditions. The third recommendation was sanctioned by the Board of Health, and in November, 1903, the people voted favorably on issuing $1,200,000 bonds for the purpose of building the works. Accordingly the sum of $46,000, approximately equally the interest for one year on the cost of the improvements, was set aside for constructing a testing station and conducting experiments to ascertain what detailed method of disposal should be adopted. This station was described in The Engineering Record of Nov. 19, 1904. Some idea of the scope of the work carried out in it may be obtained from the fact that 3,270 chemical analyses were made, 4,356 bacterial analyses, 483 special analyses for suspended matter and 130 analyses of sludge, and that an average of fifteen men were employed. As a result it was found that the best method of disposal was preliminary clarification in basins holding on an average about 8 hours' flow and operated on the septic principle, the purification of this septic sewage by sprinkling filters at an average net rate of 2,000,000 gal., and the clarification of the effluent from these filters by about 2 hours of sedimentation. The works that have been designed on this basis, illustrated in this journal on Dec. 30, 1905, have been placed under contract for the sum of $436,000, in round numbers, which compares so favorably with the $1,200,000 bond issue that no further comment is necessary to explain the value of the investigations to the taxpayers of the city. The report of the tests, which were conducted under the general supervision of the consulting engineers, Messrs. Rudolph Hering and George W. Fuller, was written by Mr. George A. Johnson, who was in charge of the work, and describes in detail all the experiments and gives the deductions to be drawn from them. While the preservation of the data in printed form will be highly useful to those who will operate the works in the future, enabling them to meet all extraordinary conditions with much less investigation than would otherwise be necessary, the volume will also become at once the leading American reference book on the subject of sewage disposal. It is understood that a limited number of copies will be sent to engineers applying for them, but owing to the exhaustion of the appropriation for the investigations, applicants for copies must enclose nineteen cents for postage, a requirement that speaks well for the scrupulous administration of affairs by the Board.

COAL HANDLING IN THE CHICAGO SUBWAY.

The delivery of coal from the freight yards of various railroads to buildings in the downtown business district of Chicago will be commenced on a large scale through the freight tunnels of the Chicago Subway as rapidly as tunnel connections can be made with the buildings and coal handling equipment installed. A gravity coal handling and storage plant for this traffic has been completed for some time in the downtown freight yards of the Chicago & Alton Ry., and another plant of the same type is nearly finished in the yards of the Chicago & Eastern Illinois R. R. Tunnel connections have already been made to and coal handling equipment installed in a number of large office buildings in the downtown district to which coal is now being delivered through the tunnels from the gravity plant already built.

The general design of the plant in the Chicago & Alton yards is shown in one of the accompanying illustrations. This plant is within less than a mile of the central part of the most congested business district of the city. It consists of three large rectangular concrete-lined hoppers, with their tops just above the ground surface in the yards. The hoppers are placed end to end, covering an area 240x80 ft. in plan at the ground level. Two of the yard tracks are carried longitudinally across the hoppers on transverse steel girders, with their ends embedded in the side walls of the hoppers, and on the transverse partition and the end walls of the latter. One hopper has a circular concave bottom; the bottoms of both of the other hoppers are divided in two circular concave sections. Leading from the center of the bottom of each concave section is a vertical chute, 2.5x3 ft. in cross-section, which extends down to two short inclined chutes built through the arch of a connection with the tunnel system that has been driven longitudinally under the hoppers and about 480 ft. below the ground level.



Gravity Coal Handling Plant in Chicago & Alton R'y Yards

The hoppers are covered with substantial shed, with an iron roof on a truss frame. The side and end walls of the hoppers have heavy monolithic concrete sections designed to resist the heavy pressures that may come against them on the outside from traffic in the yards. The partition walls are of reinforced concrete. The circular bottoms and the chutes leading from them to the tunnel are lined with concrete, the latter being cased on the inside with steel plates to avoid abrasion. The lower end of each of the two inclined chutes, which extend into the tunnel from the bottom of each vertical chute, is fitted with a valve that controls the opening.

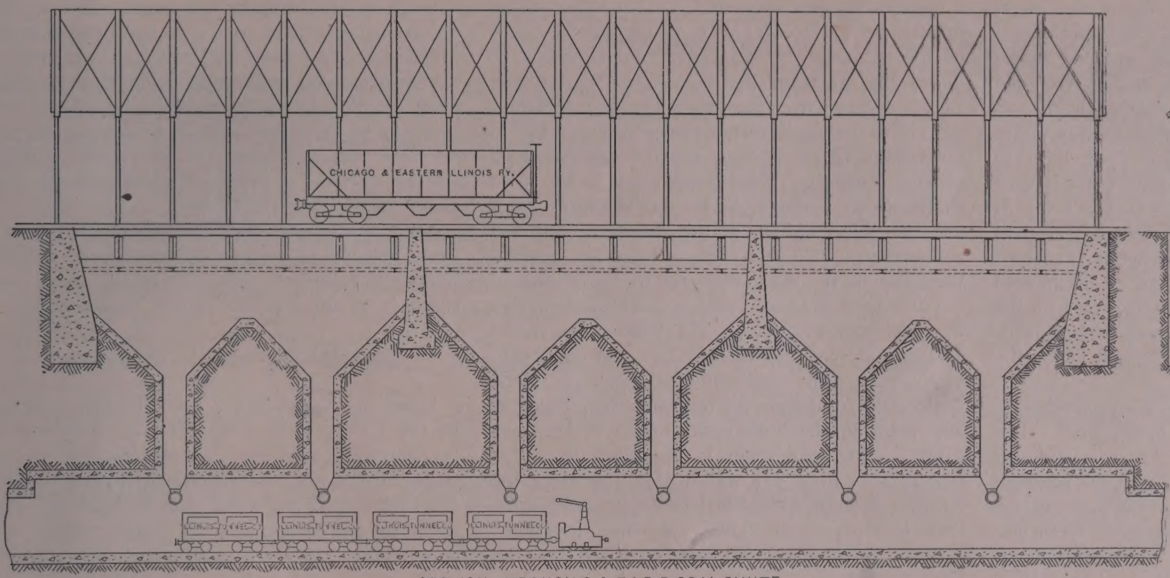
Standard gauge, side or bottom-dump cars are run over the hoppers on the tracks connecting with the railroad yards and the coal dumped from them by gravity into the hoppers. The connection with the tunnel system has a single track. It passes around a loop just beyond the coal handling plant, each end of the loop having a separate connection with one of the main tunnels of the system of tunnels. The cross-section of this connection is the same as that of the tunnels of the main system, which are 6 ft. wide by 7 ft. 6 in. high in the clear, with a flat floor and an arched roof. Trains of 3 to 8 cars handled by an electric locomotive, are used in the coal traffic. These cars have two four-wheeled trucks of the regular 28-in. gauge used in the tunnel. The body of the car has a steel frame, with sheet-steel sides and ends. The inside dimensions of the car body are 10 ft. 8 in. long, 3 ft. 8 in. wide and 4 ft. high, giving a capacity of about 5.5 cu. yd. or approximately 6 tons of coal. The cars are arranged to dump from both sides, the sides being divided longitudinally in two equal parts, each of which is hinged at the top to the car frame so that the lower or the upper half of the side may be opened separately or both halves opened at the same time. Other types of cars will probably be adopted if different requirements are made as the traffic develops. The inclined chutes leading into the tunnel from the hoppers are so spaced that all of the cars of a 6-car train can be loaded at the same time. A tunnel car has been loaded from the chutes in 1 min. 20 sec., and under normal operating conditions the loading can readily be done in 2 min. to a car.

The gravity loading plant under construction in the yards of the Chicago & Eastern Illinois R. R. is about a mile from the central business district. The general design and construction of this plant is very similar to the plant in the Chicago & Alton yards. This plant is, however, considerably larger than that one, and has six hoppers for receiving coal from the railroad cars. These hoppers cover an area of 30x135 ft. at the top, and are arranged in two rows of three each. Their side and partition wall construction is practically the same as that of the plant already described. The bottom of each hopper is divided into two equal parts, each part being sloped to a chute leading to a tunnel connection which extends longitudinally under the plant, 42 ft. below the grade of the yard.

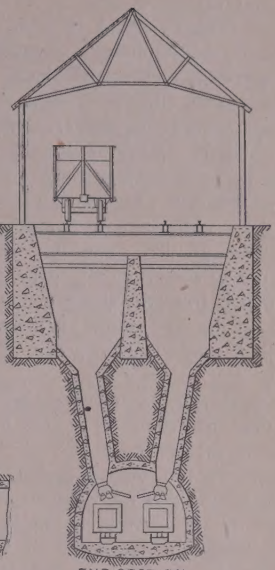
This tunnel connection is 14 ft. wide and 10 ft. high in the clear, providing room for two parallel tunnel tracks, with sufficient space between cars on the tracks to operate valves which control the lower ends of the chute leading down from the hoppers. The double-track section of the tunnel connection is joined at each end to the system of tunnels by a standard-sized, single-track tunnel. The advantages of the arrangement of this plant over the plant in the Chicago & Alton Ry. yards are several. The three hoppers in the latter permit only as many grades of coal, or different kinds of materials being handled in that plant at the same time. The six hoppers in this plant present an opportunity for handling simultaneously six grades of coal, or six different kinds of materials. The double-track tunnel connection and the arrangement of the chutes from the hoppers over the tracks also permit more cars to be loaded at the same time than can be handled in the first plant built.

A single track tunnel of the main system of tunnels has been built along the center line of practically every street in the downtown district of the city. These tunnels are all approximately 42 ft. below the street grade. They are connected in various ways with buildings along the streets under which they pass. Three general types of connections have been made for handling coal traffic, two of which are applicable for handling various other kinds of freight which will be carried in the subway.

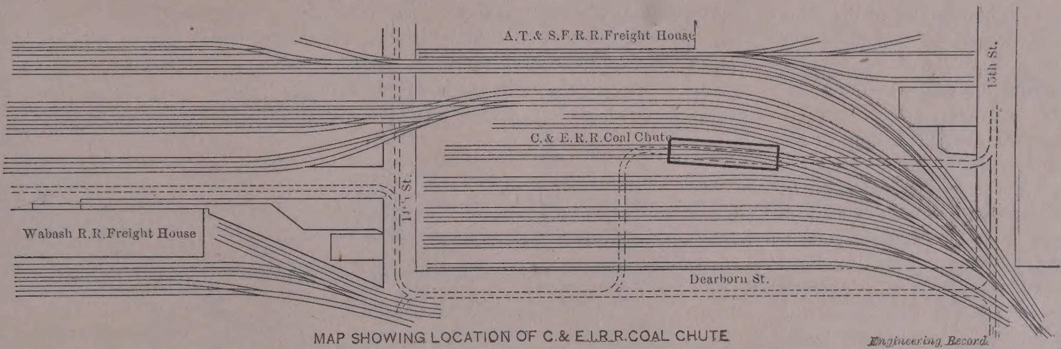
A connection with the new Majestic Theater building is a good example of one type of the tunnel connections for coal traffic. This building is 72x192 ft. in plan and 20 stories high, with its mechanical plant in the first basement. A by-pass to the tunnel under the street on which the building fronts, is built at one corner of the building, the inner edge of the by-pass being inside the curb line of the street, and the track in the tun-



SECTION THROUGH C.& E.I.R.R.COAL CHUTE

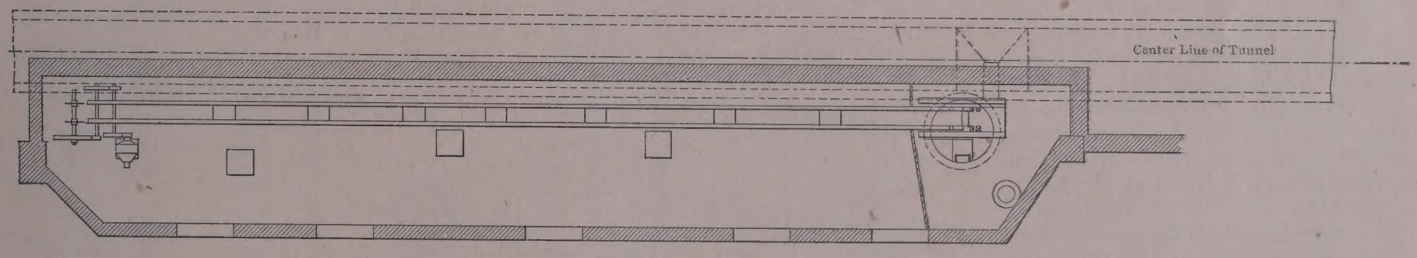


END SECTION

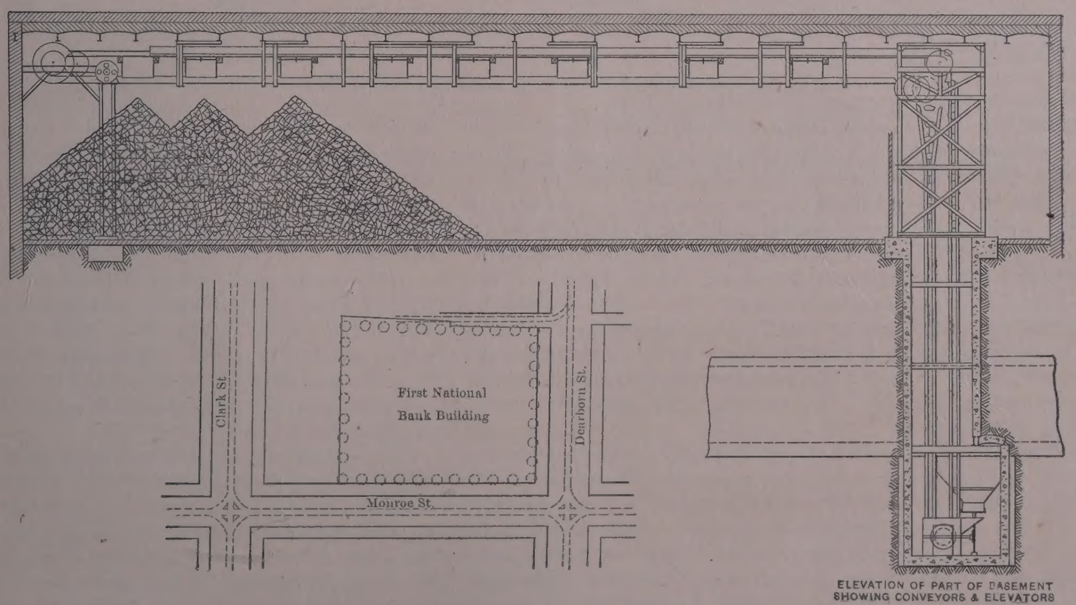


MAP SHOWING LOCATION OF C.& E.I.R.R.COAL CHUTE

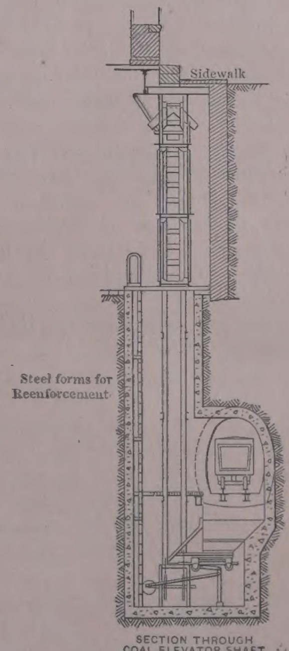
Gravity Coal Handling Plant in Chicago & Eastern Illinois R. R. Yards.



PLAN OF COAL ROOM IN BASEMENT OF BUILDING



ELEVATION OF PART OF BASEMENT SHOWING CONVEYORS & ELEVATORS



SECTION THROUGH COAL ELEVATOR SHAFT

Coal and Ash Handling Connection for First National Bank Building.

nel and in the by-pass 42 ft. below the street grade. The basement in which the mechanical plant of the building is located extends under the sidewalk to the curb line. A concrete-lined shaft, slightly elliptical in cross-section, being 7x8 ft., was sunk in the corner of the areaway under the sidewalk from the basement floor level to 55 ft. below the street grade. This shaft is connected with the tunnel by-pass at the level of the floor of the latter. A trap door is placed in the floor of this connection between the shaft and the by-pass so that coal may be discharged through it from the side-dump tunnel cars on the track in the by-pass on an inclined surface leading to a steel-lined hopper in the bottom of the shaft.

A vertical bucket elevator, on a strap-and-side-bar link steel chain, is erected in the shaft. The inclined surface on which the coal is dumped through the trap door is arranged so the contents of the tunnel cars are dumped at the front of the bottom of the elevator in the hopper. Each elevator bucket is supported at both ends by an arm braced out from the side-bars of the chain. The elevator is designed to handle run-of-the-mine coal. The bucket arms project beyond the outer edge of the bucket and pick up the largest lumps, at the same time relieving the edges of the buckets from the most severe usage.

The top of the elevator is near the ceiling of the portion of the basement of the building under the sidewalk. The boilers of the mechanical plant of the building are equipped with Dutch-oven furnaces and are arranged in a longitudinal row in the main part of the basement. An overhead trackway, made of two steel channels, extends from the top of the elevator to and along the front of the boiler furnaces. The elevator buckets discharge by gravity into a steel car, which holds between 5 and 6 tons, suspended on wheels on the overhead trackway. The car is moved back and forth along the trackway by a cable on a drum fitted with a tight and loose pulley and a double reversing belt arrangement.

A track scale is built between the elevator and the first boiler furnace in the row of furnaces so the car may be weighed at any time. The Dutch ovens are fed through an opening in the top. Coal can be discharged from the car to a storage space which holds about ½-ton around each furnace opening, or to a large storage space in front of the furnaces. The car can be hauled back to the scale and weighed after coal for one furnace has been supplied, so that an accurate amount of the coal consumed by each furnace may be readily kept. The coal elevating and weighing system was designed and installed by the H. W. Caldwell & Son Co., of Chicago. Although designed principally to handle coal, the projecting arms which carry the buckets were made heavy enough to carry a 600-lb. oil barrel so that the boiler room supplies can also be brought in through the tunnel and elevator. A platform built around the latter at the floor level of the connection between the shaft and the tunnel by-pass enables these supplies to be readily loaded on the elevator.

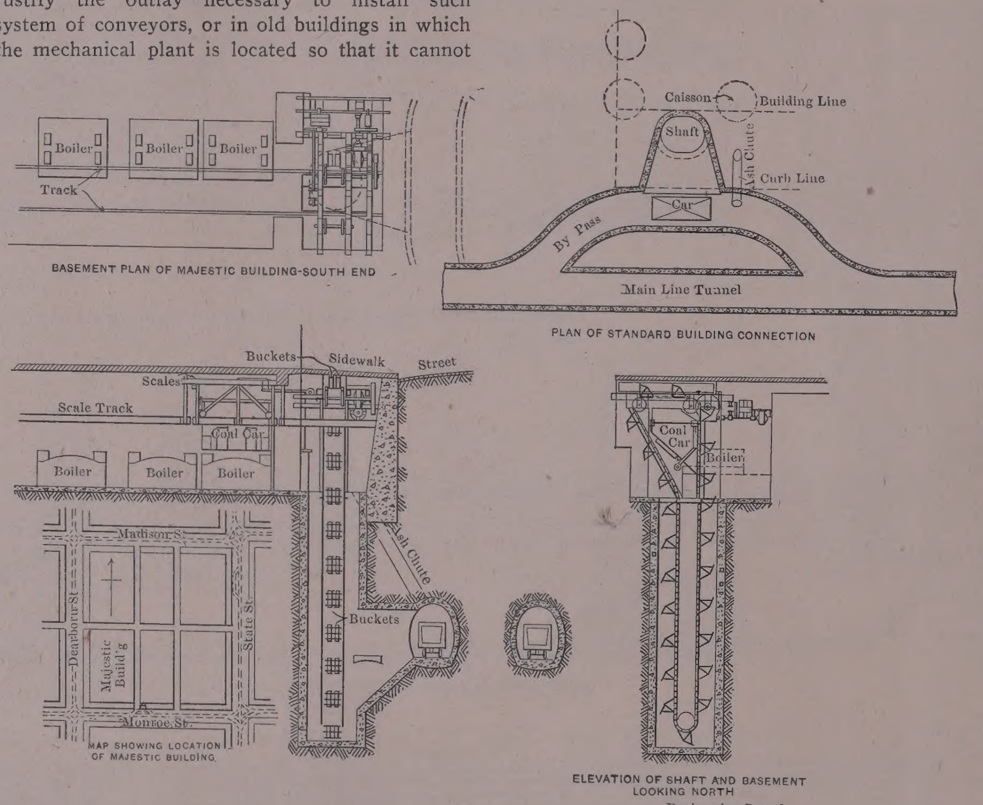
No conveying machinery has been installed in this building for handling ashes. A chute 3 ft. in diameter, however, extends from the basement, to the tunnel by-pass and ashes will be discharged through this. The space in the basement was so extremely limited after the mechanical plant had been installed that no space was available for storing ashes. By placing a gate on the bottom of the chute, the ashes produced in 24 hr. can be stored in the latter and then removed through the tunnel.

A coal elevating and conveying plant has been installed in the new First National Bank building, which is entirely different from the one just described. This plant is built to handle coal from a connection with the subway to a storage room in front of a row of boilers in the sub-basement of the building. A steel-lined hopper is placed under the track in the tunnel connection, and coal is dumped from the tunnel cars into this hopper. An automatic reciprocating feeder, built in the bottom of the hopper, supplies the coal to a gravity discharge elevator-conveyor built in a shaft, which extends up to the basement floor level of this building, at the side of the tunnel connection. The elevator-conveyor is erected vertically in the shaft reaching to the ceiling of the basement and then extends horizontally across the coal storage room. The buckets on it are arranged so that they replace the usual flight conveyor, and with a specially designed automatic device, the coal can be dumped from them at any point in the horizontal portion of the conveyor. The coal room is separated from the boilers by a brick fire wall with doors along the bottom through which coal is discharged on the floor in front of the boilers and fired by hand.

Both of the elevating and conveyor installations described are each an example of the general types that are applicable for large, new buildings. Where the coal consumption is too small to justify the outlay necessary to install such system of conveyors, or in old buildings in which the mechanical plant is located so that it cannot be reached readily by a conveyor system, a third method of delivering the coal is employed. Such an arrangement has been made for an old 4-story office building at 177 Monroe St. A by-pass to the tunnel extends under the front of the building and is connected to the basement of the building by an elevator shaft. Loaded tunnel cars are raised to the basement floor level by an elevator large enough to handle one of the tunnel cars which is installed in the shaft. A track is laid along the basement floor to mechanical plant at the rear of the building. The ashes are removed in the empty coal cars.

The capacity of the tunnel system to handle coal is practically unlimited. Tunnels are built under the downtown distributing freight yards of every railroad in the city. A tunnel car containing between 5 and 6 tons of coal can be loaded at the railroad yards, delivered to the consumer in the downtown business district in very much less time than is required under the most favorable conditions with teams. One of the most objectionable classes of traffic may also thus be diverted entirely from the streets. Furthermore, the unloading of wagons by hand through manholes in the sidewalk, resulting in the partial blockade of the street, and the littering of the latter with coal and ashes can be entirely avoided where the coal and ash handling service available in the subway is employed.

The operation of the tunnel system of the Chicago Subway is under the supervision of Mr. George W. Jackson, general manager and chief engineer of the Illinois Tunnel Company.



BASEMENT PLAN OF MAJESTIC BUILDING-SOUTH END

PLAN OF STANDARD BUILDING CONNECTION

MAP SHOWING LOCATION OF MAJESTIC BUILDING

ELEVATION OF SHAFT AND BASEMENT LOOKING NORTH

Engineering Record

Tunnel Connection for Handling Coal and Ashes, Majestic Theater Building.

Concrete Pavements in Denver.

Some years ago Mr. C. A. Trease, engineer of the Denver City Tramway Co., proposed to lay concrete pavements between the rails of the tracks in the business districts of the city. This proposition was regarded with considerable disfavor by the Department of Public Works, but was finally approved. The space between the rails, 3½ ft., and a strip 2 ft. wide outside the rails was paved with a 3-in. base of 1:3:7 concrete and a 3-in. top of 1:2:4 concrete. For the base gravel from ¼ to 2 in. in size was used, while basalt crushed to the same range of sizes was employed in the top course. No attempt was made to provide for expansion and contraction, the pavement is continuous, and is a solid mass from the bottom of the base to the surface, the top layer having been placed by a separate gang which followed closely the gang that laid the base. These street railway pavements are giving entire satisfaction, even at street intersections where they have to sustain much more traffic than the pavement between the rails does.

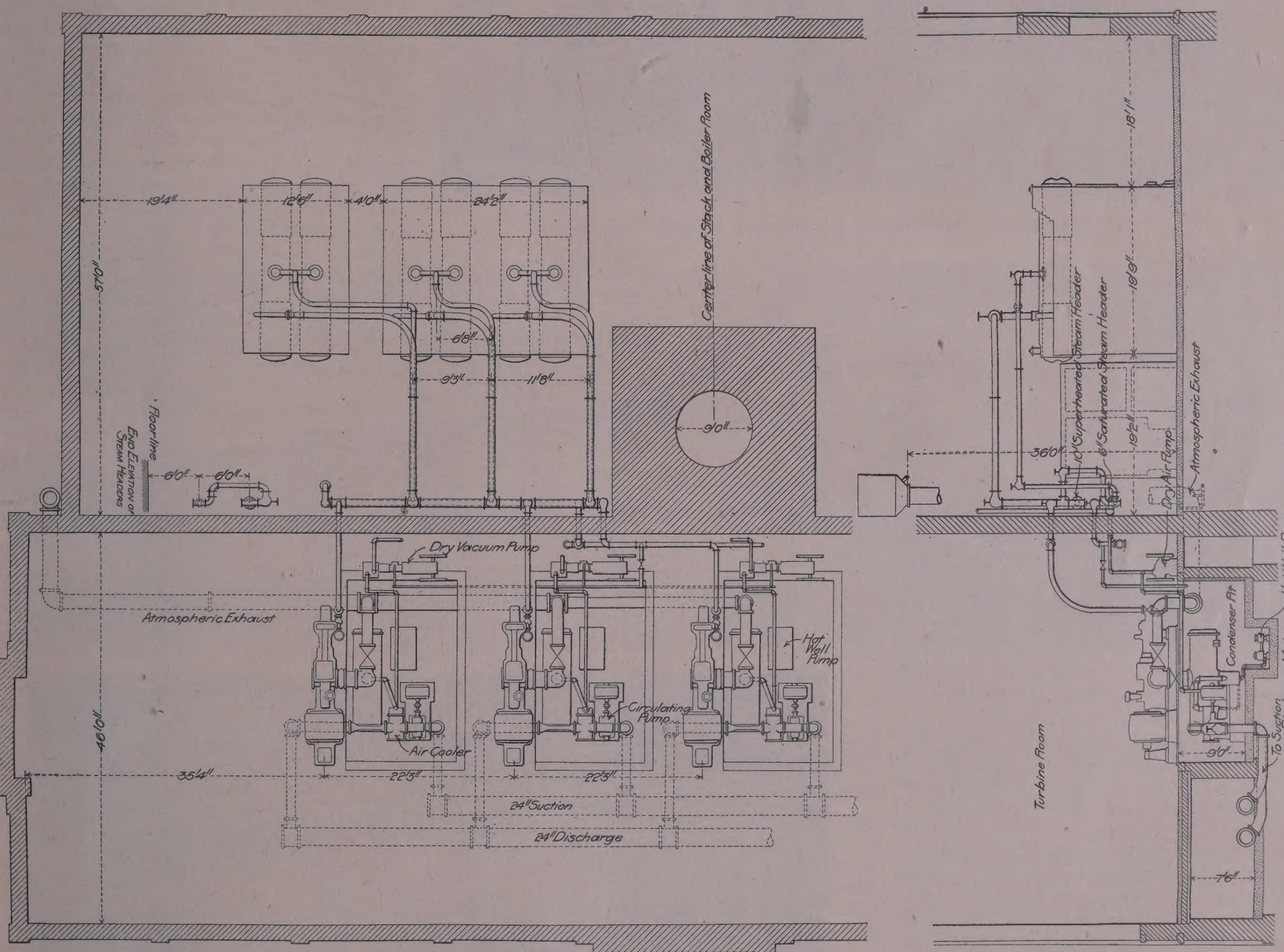
This experience was so satisfactory that last year the Board of Public Works decided to pave a number of alleys with concrete. The roadbed for such work was graded at a depth of 9 in. below the finished surface, and soft places filled in the usual manner. Small dams were then built across the roadway, high enough to ensure at least 6 in. of water over the center and 2 in.

at the highest point of the subgrade. The distance between the dams varied according to the grade. Water was admitted until the desired depths were obtained, and then left to sink away. When it had disappeared, the surface was rolled and any soft places were again filled and puddled.

When this work was finished a bed of cinders or sand mixed with gravel was placed on the subgrade and compacted by wetting and rolling until it presented a smooth, hard surface 6 in. below the surface of the finished pavement.

On this foundation was laid a 4-in. base of 1:3:7 Portland cement concrete, and then a 2-in. layer of 1:2:4 concrete. The stone or gravel for the base was ½ to 1½ in. in size, and that for the upper course ½ to 1 in. The concrete was mixed by hand on a sheet of steel about 12 ft. square, kept just in front of the work. The base was first laid in sections of 10 ft., each section being the full width of the alley or 16 ft. Immediately after completing a section of the base, the materials for the top were mixed and placed, thus securing a perfect bond between the base and top. The sheet of steel was then moved 10 ft. ahead to make room for the succeeding section and the operation repeated.

The contract price was 55 cents per cubic yard for grading and $1.08 per square yard for the pavement. This price includes a five-year guaranty. The experience gained on this work during 1905 indicates that it may prove desirable to lay the concrete in a single course, using probably the richer mixture.



Details of Turbine Lighting Plant. Showing Arrangement of Steam Piping.

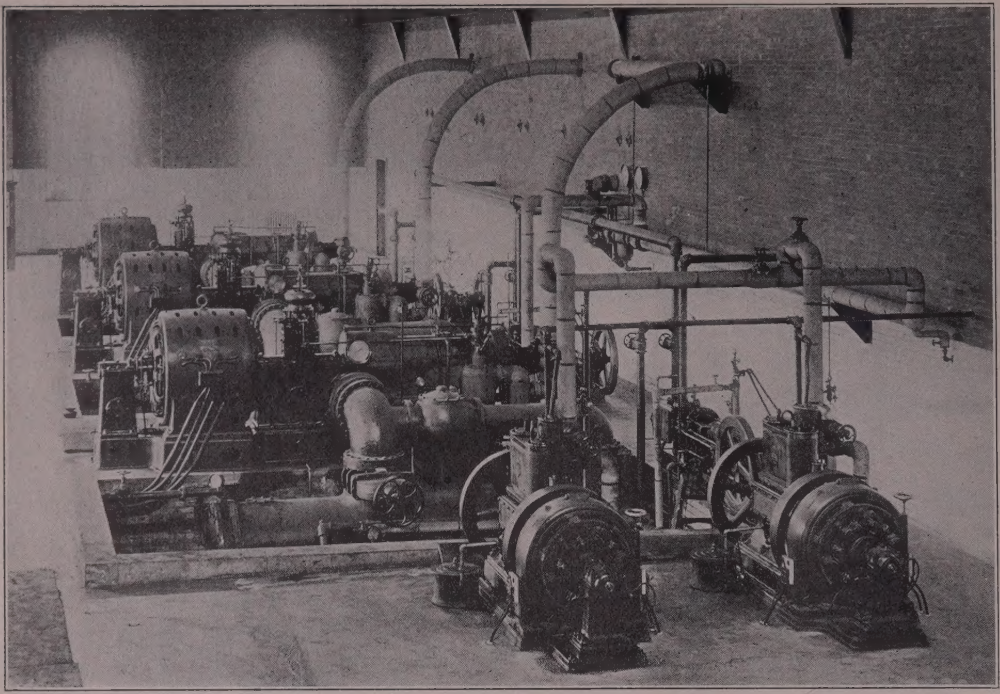
A Municipal Steam Turbine Station at Columbus, Ohio.

The city of Columbus, Ohio, has been operating a steam turbine station for street lighting since late in 1904, although the installation was not completed to its full capacity until early in the summer of 1905. The service furnished is for street arc lighting only, so that the load on the station favors economical operation during the night, but presents wasteful conditions owing to absence of a day load and the consequent stopping and starting.

The station is in the western part of the city alongside the Olentangy River, which furnishes ample circulating water for condensing operation. The building, which is of brick with sandstone trimmings, has a 46x156-ft. turbine room and a 57x160-ft. boiler room, with brick partition wall, and each side has an independent wooden roof carried on steel trusses. The floors are concrete arches sprung between I-beams. The turbine room is spanned by a 10-ton Pawling & Harnischfeger hand-operated traveling crane and both roofs are surmounted by monitors with swinging sash for lighting and ventilation.

About one-half of the ultimate capacity of the station has been installed, consisting of three 300-h.-p. Babcock & Wilcox inclined-header water-tube boilers and three 600-h.-p. Westinghouse-Parsons turbine generating units, with the necessary auxiliaries. The ratio of boiler to turbine rated capacity is about 55 per cent. and the space occupied by each turbine unit with its complete auxiliaries and switchboard is but 2½ sq. ft. per kilowatt capacity. The entire turbine room averages 3¼ sq. ft. per kilowatt, the boiler room, 4.15 sq. ft., and the total power house 7½ sq. ft. The boilers are equipped with Babcock & Wilcox standard superheaters, suspended between the drums and water tubes, each able to raise the steam temperature from 100° to 140° above that due to the pressure of 150 lb. carried; an average superheat of 110° is secured which is easily maintained nearly constant with careful firing. The boilers are fitted with Roney mechanical stokers operated by a 4½x4-in. Westinghouse standard stoker engine. The products of combustion pass to the stack through a breaching of brick and steel construction and a Broomell, Schmidt & Stacey economizer, which has a by-pass connection for cutting the economizer out if necessary. The stack is a brick chimney 150 ft. in height having a diameter within the lining of 9 ft. and is located in the center of the boiler room, midway between the present and future batteries of boilers.

The coal for the plant is mechanically handled to elevated bunkers over the firing floor, from which it is delivered directly to the stoker hoppers by special weighing chutes, of which there is one for each boiler. The coal is discharged into the weighing hopper by under-cut gates controlled from the floor, the weighing being accomplished in a special scale box suspended within easy reach from the floor. This equipment is used not only to check mine weights, but also to keep records of plant operation, the usual method



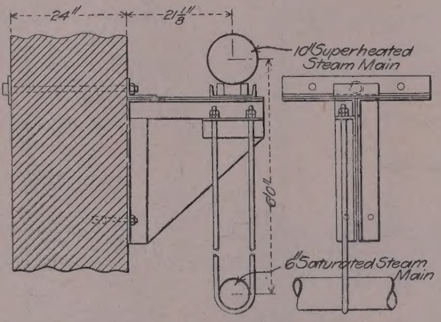
Turbine Room of the Columbus, O., Municipal Lighting Plant.

of weighing the entire car loads of coal as received having been departed from. The coal used is charged against the plant only as it is required and the weights are recorded independently of bunker capacity or other coal storage. The duty of the plant from day to day or even for a part of a day's run may thus be accurately determined. The coal used is a low-grade Ohio slack, which is delivered by a screw conveyor to the boot of a bucket elevating conveyor which raises it to the boiler house monitor; in the latter a longitudinal scraper type conveyor distributes the coal to the various bunkers. The various conveyors are driven by a small vertical automatic engine, which, together with the entire coal handling equipment, was furnished by Huyl & Patterson. The bunkers are supported independently of the walls and boiler settings and each holds 15 tons of coal. The ashes are removed by hand from the inclined ash pits into a tunnel beneath the firing floor.

There are duplicate Worthington boiler feed pumps and delivery piping. The feed water is heated in a 1,000-h.-p. Cochrane open feed-water heater with attached oil separator, nearly all of the plant auxiliaries being steam driven for the purpose of utilizing the exhausts in the heater. The feed piping is arranged to permit the pumps to deliver from the open heater through the economizers for additional heating before entering the boilers, or direct to the boilers if desired. The condensation returned from the turbine condensers to the open heater forms the greater part of the feed-water supply, artesian well water being utilied for make-up.

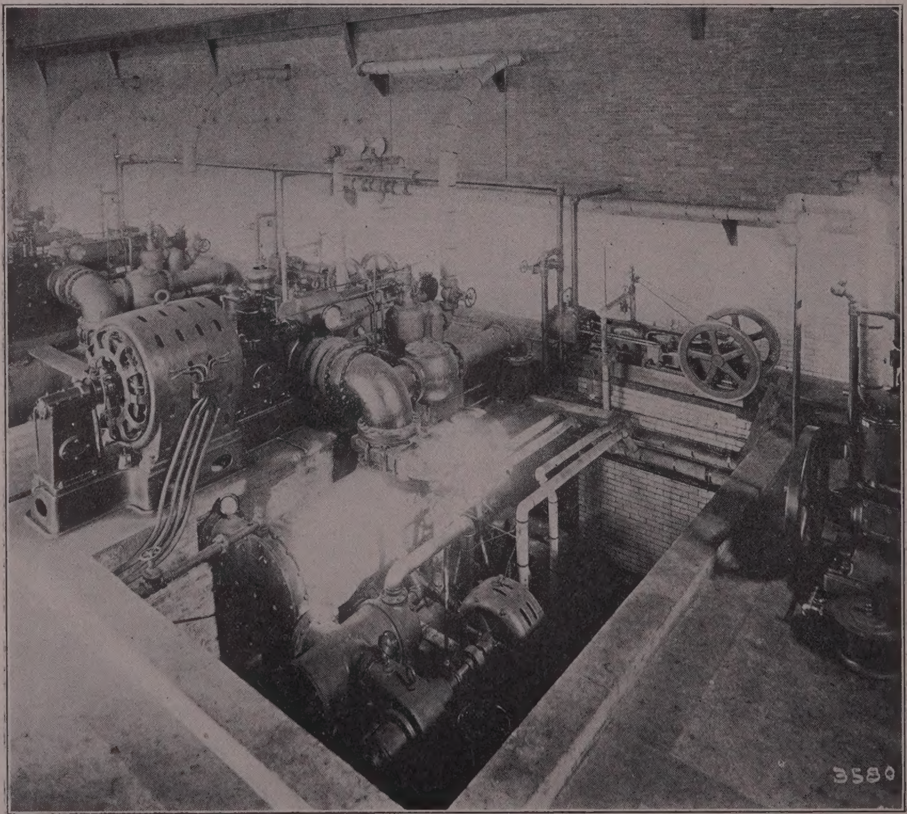
There are independent piping systems for the superheated and saturated steam, arranged to permit of interchangeability of both saturated and superheated headers and the supply of steam to the turbines with any degree of superheat. As shown in the plan and cross-section of the station equipment (reproduced from drawings of Westinghouse, Church, Kerr & Co.), there is a 10-in. header on the boiler room side of the division wall for the superheated steam, immediately below which is the 8-in. saturated steam header. The former has 8-in. branch connections to the superheated steam nozzles of each boiler while the saturated header has 5-in. branches to each boiler, both of these having Pearson non-return valves at the boiler nozzles for their protection in case of rupture of a tube. The turbine supply connections are 5-in. branches from the superheated header, which are carried from angle valves on top of the header through the division wall with long radius bends down to the turbine throttles. An interesting feature of the piping is the provision made for the supply of saturated steam to the turbine, or superheated and saturated in any desired degree of mixture, which is accomplished by means of cross-connections between the two headers at their ends. The superheater equipments are also arranged for the delivery of saturated steam only if desired, flooding connections permitting any superheaters to be operated merely as additional boiler heating surface for the supply of saturated steam.

The two headers are both carried by a single line of brackets on the boiler room side of the division wall. The brackets have rollers on their upper faces on which the superheated main rests, while the saturated main is suspended 6 ft. below by U-shaped loops of ¾-in. round iron; the details of this bracket and hanger are shown in an accompanying engraving (reproduced from drawing of Westinghouse, Church, Kerr & Co.). The bracket consists of a ½-in. plate with angle stiffeners at back and top with an angle plate at the rear by which it is bolted to the wall. The superheated header rollers rest in short lengths of 6-in. channel arranged to permit of a 6-in. movement of the roller. The saturated header hanger is suspended beneath on a small angle bracket as shown. All the piping has been installed with flanged joints and corrugated copper gaskets, and long radius bends are used to provide for expansion.



Details of Steam Header Supports.

The three turbines are of the standard Westinghouse-Parsons type of 600 h.-p. rated capacity each, and overload capacities of 50 per cent. They run at 3,600 r.p.m. and are operated in parallel with ease through a simple governor adjustment. Each unit is fitted with a secondary valve which operates automatically to protect the turbine in case of loss of vacuum, and an independent oiling system is used upon each unit, direct attached and driven by the turbine itself. The oil is circulated under a slight pressure through the bearings, cooled and returned to the oil reservoir for con-



Arrangement of Condenser Equipment in Pits alongside Turbines tinuation of the same cycle, and the loss is so slight that a single charge of the oil of a comparatively low grade lasts for two to three weeks, after which it is drawn off for use in the low-speed machinery of the plant. The generators are of the standard Westinghouse two-pole, revolving-field construction and deliver 60-cycle, three-phase alternating current at 2,200 volts. Excitation current is furnished by two 25-kw. Westinghouse 125-volt generators, direct-connected to Westinghouse Standard engines operating at 350 r.p.m.

The condenser for each turbine is located in a pit at one side of the turbine so as to permit a very short and direct connection from the exhaust opening to the top of the condenser, and the pits are lined with white glazed brick for cleanliness and better illumination. The condensers are of the Worthington independent two-pass surface type with 1,800 sq. ft. of cooling surface; each has an air cooler with 118 sq. ft. of cooling surface for the air connection to the dry vacuum pump. Each condenser has an independent 10-in. circulating pump of the conical type, driven by a 20-h.-p. induction motor, the water suction line being an 8-in. pipe and the discharge 10-in.; this motor operates normally considerably underloaded, the power required averaging less than 3 per cent. of the turbine rating. The hot well pumps are 5¼x4¾x5-in. Worthington steam pumps which remove the condensation to the open feed-water heater. Each unit has an independent 6x12x12-in. dry vacuum pump of the single-stage rotative type, the air line connections of which are, however, interconnected to permit any pump, or all of them to be connected with any condenser. The exhaust connection from the turbine to the condenser is a 20-in. elbow with a 14-in. side outlet to the back-pressure valve leading to an atmospheric exhaust header. The average vacuum maintained by this equipment has been 27½ in., but somewhat better results are expected during the next dry weather season, as a dam is being built across the river at the rear of the power house which will provide ample storage for the circulation system in the periods of low water. The suction and discharge mains to the dam for this water circulation are of 24-in. pipe.

The electrical equipment of the station has the usual quota of oil switches and instruments for the handling and control of the current delivered at 2,200 volts. The switchboard is a 22-panel white marble board and is located on an elevated gallery from which the operator has full view of the entire generating equipment. Three of the panels are generator panels, one a total panel and the remaining eighteen feeder panels for the series arc transformers or regulators and their arc circuits. The latter are divided into three six-panel sections, each controlled by a section oil switch, so that in event of trouble any section may be localized and operated from an auxiliary bus and separate generator. Each feeder panel controls one step-up transformer and arc regulator for the series alternating-current arc lighting circuits, and switch connections provide for cutting in a reserve transformer instantly in case of trouble to any one in regular service. The entire electrical equipment was supplied by the Westinghouse Electric & Manufacturing Co.

Until about the middle of the preceding year the plant was not operating under normal and best conditions, owing to the lack of outside load, the temporary maintenance of a "dark night" schedule, uncovered piping and some troubles at first encountered in the condenser circulating water system. High economy could not, therefore, be expected. Operating on an average of but little more than one-third of the time, the standby losses during the day evidently constitute an important source of loss. Although the load factor is high during the winter months, practically 50 per cent., the boiler plant is entirely idle during the day and must be brought up to its maximum capacity previous to starting. Thus the station necessarily wastes much heat in banked fires during the day and in building and quenching fires before and after the night's run.

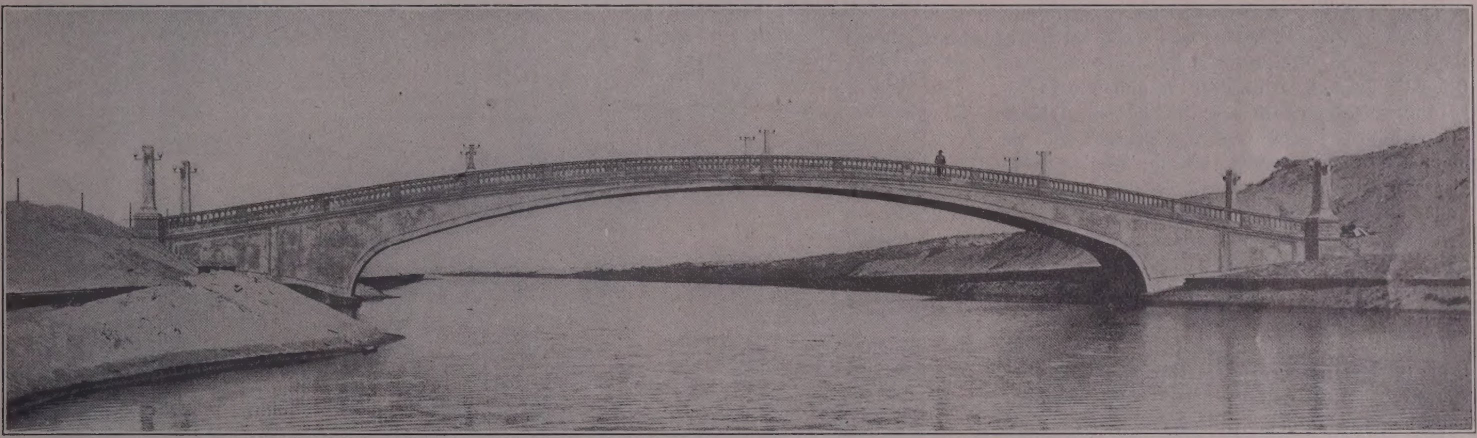
The regular station operating force consists of five men, three shifts of eight hours each; two men in the boiler room, two in the turbine room and one at the switchboard.

As evidence of the low cost of arc lighting by this system the following figures are of interest: During the year of 1905 the cost of operation of the plant on dark night schedule was approximately $34,500. Within this period the number of lamps connected was gradually increased to nearly 2,000. The average operating cost per arc was $22 per year, including all labor, supplies and the ordinary maintenance of entire system, but no betterment, taxes or depreciation; the latter is an extra charge at 5 per cent. of the equipment cost of the plant ($474,000). Including interest at 4 per cent. and depreciation at 5 per cent., the total cost to the city was $49.15 per arc for the year ending Dec. 31, 1905. Previous to the establishment of the municipal plant the arc lighting contracts had been executed by the Columbus Railway & Light Co. at a rate of $74.50 per arc. The first year's operation has thus netted the city something like $25 per lamp, exclusive of tax valuation.

In the execution of the Columbus municipal lighting project, directors, engineers and manufacturers have contributed joint effort towards its success. The building and general plant arrangement was worked out conjointly by the city architect and engineer under the direction of the Board of Public Service. Westinghouse, Church, Kerr & Co. were entrusted with the design of boiler piping and condensing plants. During the erection of the station and its subsequent operation Mr. William Wilcox has been in immediate charge as superintendent of the Department of Public Lighting.

The 146-Ft. Reinforced Concrete Arch at Playa del Rey, Cal.

There has recently been constructed at Playa del Rey for the Los Angeles Pacific Ry. a reinforced concrete foot bridge 205 ft. 8 in. long, 19 ft. wide, 146 ft. in clear span and having a rise of 18 ft. There are three arch ribs, each 14 in. thick and 24 in. deep at the center, including the floor thickness, which is 4 in. These ribs spring from beds of concrete, strengthened by grillages of rails and resting on pile foundations. At the abutments the spandrel and cross walls form boxes which are filled with loose stones without concrete. The ribs are reinforced by four 3½x2½x¼-in. angles one at each corner, connected vertically by 1½x¼-in. bars, and by three 24-lb. rails, one over the other. The transverse beams are 6 in. wide, each reinforced by a rail of the same weight, to the ends of which iron plates are riveted so as to form brackets reinforcing the kneebraces at the connections of the transverse and main beams. The 4-in. floor is reinforced by a network of ⅜-in. bars 5 in. apart and crossing the bridge diagonally. The centers were kept in place for seven weeks after the concrete had been put in place. When the centers were struck a settlement of ⅜ in. was noted, which increased nearly to ½ in. during the following day, since when no further change has been observed. The bridge was tested with a load of 3½ tons per square yard. It was designed and built by Mr. Michael De Palo, of Los Angeles.



Reinforced Concrete Bridge of 146 Feet Clear Span at Playa del Rey

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ENTROPY has been a term replete with mystery to many readers, and for this reason attention is called to the following explanation of it, contributed to "The Engineer" of London by Prof. Sidney A. Reeve, of the Worcester Polytechnic Institute: "Entropy is to the motion of an engine piston what the mass of the pile driver hammer is to the pile; what the mass of the pneumatic hammer head, with its repetition of blows so rapid as to constitute an almost continuous impulse, is to the cold chisel which it propels. It is simply the mass involved in that molecular bombardment of the engine piston which we call the heat of the steam. The bombardment is the heat; the muzzle velocity of the projectiles is its temperature; the mass of the broadside is the entropy involved."

A Discussion of Formulas for Concrete Beams.

One of the most interesting papers on reinforced concrete that has appeared for some time was presented a few weeks ago by Mr. Henry Goldmark to the Canadian Society of Civil Engineers. It was a discussion of the various theoretical formulas that have been proposed for beams, and is particularly instructive as an explanation of the essential similarity of many such expressions, although they appear very different at first glance. They are based on the common theory of flexure of homogeneous materials, with modifications due to the composite nature of the beam and the properties of concrete differing from those of steel and timber.

In structural steel beams the modulus of elasticity is practically the same for all grades of steel, and remains constant for all stresses below the elastic limit, hence formulas can readily be obtained for the stresses and deformations under any given load. The modulus of cement concrete on the other hand depends on the composition of the concrete, the mode of mixing, the age of the concrete, etc.; furthermore, it probably varies with the unit stress acting on the concrete. The neutral axis, which in steel beams is fixed by the geometrical figure of the cross-section, in the case of concrete depends also on the ratio of the modulus of the steel to that of the concrete, and the ratio of the quantity of steel used to that of concrete. The latter ratio is fixed for any given beam, the former varies with the unit stresses according to laws which are little known. Hence, the position of the neutral axis changes with the loading. For this reason it is not feasible to devise any general formula for stresses and strains under different working loads.

It is, however, possible to determine the maximum loading a beam can carry without rupture and from this to proportion beams with proper factors of safety.

It is true, as stated above, that under working loads the concrete usually carries part of the tensile stresses. If, however, the loading be gradually increased, a point will eventually be reached at which the concrete on the tension side will tear apart, showing fine cracks. The beam will still be far from failure, as the tension in the steel at this stage will usually be well below the elastic limit. If the loading be still further increased the entire tensile stress will now be carried by the steel reinforcement. Failure will not occur until the steel is stressed beyond its elastic limit, or the concrete crushed on the compressive side of the beam. The elongation which the concrete itself can stand without cracking appears to be somewhat increased by the reinforcement. Still, in a well-proportioned beam there will usually be some tearing apart of the concrete on the tension side under a load which does not utilize fully either the tensile strength of the steel or the compressive strength of the concrete. Hence, it will result in more economical and still perfectly safe construction, to assume that at breaking loads all tensile stresses are resisted by the steel reinforcements only. Some engineers believe that no appreciable cracks appear on the concrete until the elastic limit of the steel has been passed, and hence they take into account the tensile resistance both of the concrete and of the steel. The tests on which this view is based still await full corroboration.

To sum up, then, two different assumptions are made: (*a*) That the steel carries all tensile stresses; (*b*) that the concrete takes part of them.

Most formulas now in use are based on the first assumption, but some engineers with a high reputation as experimenters and practical designers, have adopted the latter hypothesis in calculating stresses.

A second mooted point is the shape of the stress curve; that is, the law according to which stresses in given cross-sections vary from zero at the neutral axis to a maximum at the outer edge of a beam.

Apart from these two points, the difference in the various formulas is largely a matter of algebraic arrangements. There is, of course, much difference of opinion as to the proper values for the working stresses and the elastic moduli, which should be assumed in any given case. The entire question will be more clearly understood by working out a general formula, and showing how methods of calculation given by different writers can be derived from it.

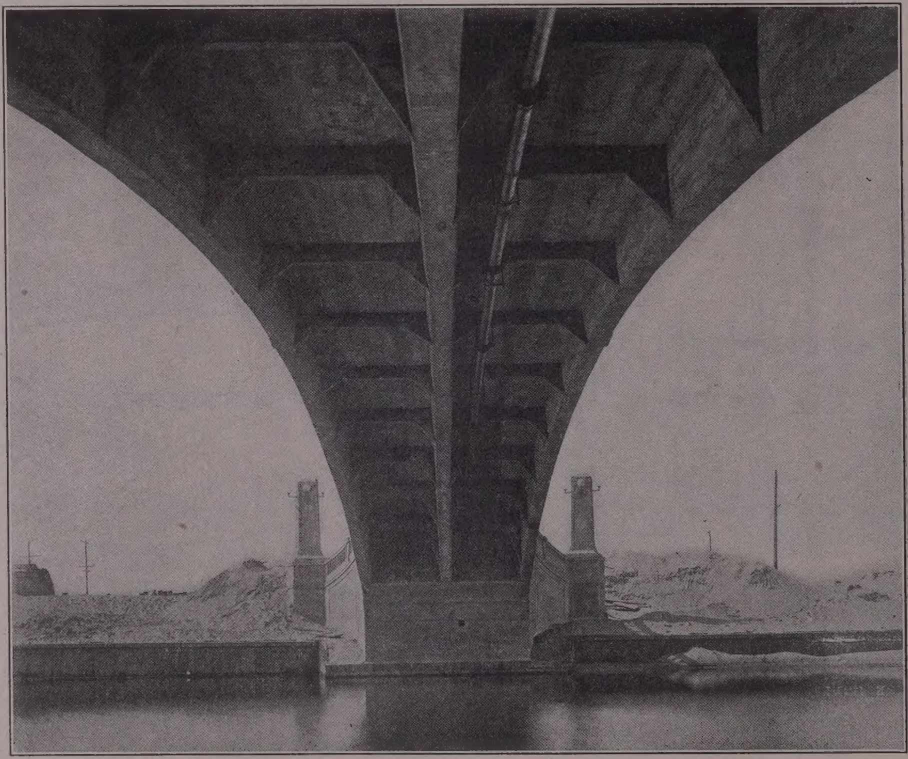
The most usual case is a rectangular beam reinforced on the tension side only and loaded vertically. It is assumed that the steel adheres to the concrete and that the two materials act together perfectly. The fact that the coefficient of expansion of steel and concrete is the same makes this last assumption possible. There are also supposed to be no initial stresses on either material.

As in the case of steel beams, sections plane before bending are assumed to remain plane after bending. Experiments appear to prove this to be correct. When the beam is loaded and bends, there will be compression extending down for a certain distance from the top, the lower edge of this compression area being the neutral axis. Below this point the concrete is supposed to open up and all tensile stresses to be carried by the steel.

Let b and h = breadth and total depth of beam.
d = the efficient depth, i. e., the depth to the center of the steel.
y_1 = distance to neutral axis from top of beam,
y_3 = distance of centroid of compressive stresses from neutral axis.
l_1 = compression of concrete (at top) per unit of length.
l_2 = extension of steel per unit of length.
E_c = modulus of elasticity of concrete.
E_s = modulus of elasticity of steel.
$e = E_s/E_c$.
C = compressive stress per square inch on extreme fibre of concrete at maximum load.
T = tensile stress per square inch in steel.
P_c = total compressive stress on cross-section.
S = area of steel reinforcement.
M_o = moment of resistance of cross-section.

If E_c is taken as constant for all stresses, the stress diagram will be triangular. This is the case for steel, timber or other homogeneous materials. This assumption is also made very generally for concrete steel beams and is contained in the building codes of most cities, and of the Prussian and other governments. This gives the total compressive stress $P_c = \frac{1}{2} C b y_1$ and the distance from centroid to neutral axis $y_3 = \frac{2}{3} y_1$.

Actual compressive tests in concrete seem to indicate that the rectilinear assumption is not correct, and that the line of stress is curved. It is frequently taken as a parabola with its vertex on the neutral axis of the beam and its axis vertical. This gives $P_c = \frac{2}{3} C b y_1$ and $y_3 = \frac{3}{5} y_1$. After making a careful study of many recent tests Capt. John S. Sewall, U. S. A., proposes as a safe compromise, a curve which gives: $P_c = \frac{5}{8} C b y_1$ and $y_3 = \frac{3}{5} y_1$. Mr. A. L. Johnson makes $P_c = \frac{5}{8} C b y_1$ and $y_3 = \frac{2}{3} y_1$; but he also takes into account the tensile stresses in the concrete.



Main Ribs and Transverse Beams of Playa del Rey Bridge.

General Formula.—As a general expression we can use $P_c = n C b y_1$ and $y_3 = m y_1$.

In homogeneous beams the moment of resistance and the stresses can be found by simple statics. The algebraic sum of the axial forces acting on any cross-section and also the moments of these forces about any point in the section must equal zero. These conditions give two equations which solve the problem. In a composite beam these two statical equations are not enough. We must add a third taken from elasticity.

The three equations thus found are as follows:

$$P_c = S T = n C b y_1 \tag{1}$$

$$M_o = P_c (y_3 + y_2) = S T (y_3 + y_2) = P_c y_3 + S T y_2 \tag{2}$$

$$\frac{y_1}{y_2} = \frac{l_1}{l_2} = \frac{C}{E_c} \div \frac{T}{E_s} = \frac{Ce}{T} \tag{3}$$

As $y = d - y_1$ and $y_2 = my_1$, we have by substitution

$$ST = n\,C\,b\,y_1 \qquad (4)$$

$$M_O = n\,C\,b\,y_1\,(my_1 + d - y_1) \qquad (5)$$

$$y_1 = d \div (1 + T/C_e) \qquad (6)$$

In the last three equations e depends on the materials only, and n and m on the assumption made for the stress curve, so that these three quantities are constants for any given case. There are seven remaining quantities and only three equations. Two cases must be considered.

First.—To find the strength of a beam of given dimensions and reinforcement.

Here b, d and S are known.

There remain four other quantities, T, C, M_O and y_1.

From (4) and (6) we obtain

$$y_1 = \sqrt{\frac{Sed}{bn} + \left(\frac{Se}{2bn}\right)^2} - \frac{Se}{2bn} \qquad (7)$$

which shows that the neutral axis depends merely on the amount of steel reinforcement and the elastic moduli, i. e., it is fixed in any given beam if definite values for the moduli of concrete and steel are assumed.

T and C are interdependent; that is, if a given value is assumed for T, there will be a corresponding value for C and vice versa.

The breaking strength of a concrete beam is generally supposed to correspond to a stress in the steel equal to its elastic limit, as beyond this point its extension is so great as to completely rupture the concrete surrounding it.

If we take $T =$ elastic limit of steel, the maximum moment of resistance will be

$$M_O = TS\,(my + d - y_1),$$

and the corresponding value for C will be given by equation (1). If the value of C thus obtained is excessive, T must be reduced.

Second.—For a given loading and span to design a beam in which the concrete and steel shall not be strained beyond safe limits.

Here M is given, also T and C, and n and m are also known quantities, while b, d, S and y_1 remain to be determined. As there are only three equations, they are not independent variables. If, however, the ratio b/d be assumed, S may be readily expressed as a function of T, C and e, and suitable values for b and d obtained.

Thacher's Formula.—Mr. Edwin Thacher's well-known formula may be readily derived from the equations given above.

His assumptions are the following: Steel on tension side only, steel carries all tension stresses and compressive stress curve rectilinear. And therefore, $n = \frac{1}{2}$, and $m = \frac{2}{3}$. Hence, $P_C = \frac{1}{2}\,C\,b\,y_1$ and $y_2 = \frac{2}{3}\,y_1$, and from (2) $M_O = \frac{1}{2}\,C\,b\,y_1\,(\frac{2}{3}\,y_1) + S\,T\,y_2 = \frac{1}{3}\,C\,b\,y_1^2 + S\,T\,y_2$, and by substituting from (3)

$$C = Ty_1 \div ey_2$$

$$M_O = \frac{1}{3}\left(\frac{T\,by_1^3}{ey_2} + S\,T\,y_2\right)$$

$$= \frac{T}{3}\left(\frac{by_1^3}{ey_2} + 3S\,y_2\right)$$

or if M_O is expressed in foot-pounds instead of inch-pounds,

$$M_O = \frac{T}{36}\left(\frac{y_1^3}{ey_2} + 3Sy_2\right)$$

the form given by Mr. Thacher.

Sewall's Formula.—Capt. John S. Sewall, Corps of Engineers, U. S. A., has made a careful study of concrete beams, and recommends the following method: He assumes steel in tension side only, steel carries all tension, and for a stress curve, a compromise between a right line and parabola.

He makes $n = \frac{5}{8}$ and $m = \frac{3}{5}$, so that $P_C = \frac{5}{8}\,C\,b\,y_1$, $y_2 = \frac{3}{5}\,y_1$. Hence, $M_O = \frac{3}{8}\,C\,b\,y_1^2 + S\,T\,y_2$ and $y_2 = Ty_1/C_e$.

In a later and very interesting paper Capt. Sewall has recently advocated for the breaking strength of a beam a higher value than the elastic limit in the steel and assumes that when T reaches the elastic limit of steel, the maximum compression of the concrete is equal to eight-tenths of the ultimate resistance of concrete. He then has the following expression for the bending moment:

$$M_O = 0.292\,C\,b\,y_1^2 + S\,T\,y_2.$$

In view of the uncertainty as to the value of E_C and as to the shape of the stress curve, he proposes using a constant value for the position of the neutral axis, and shows that the variations are practically not very great within the usual range of stresses.

Making the lever arm of the stresses, i. e., the distance from the centroid of the compressive area to the center of the steel $= 0.85d$, he gets the simple formula: $M_O = 0.85d\,S\,T$.

Buel's Formula.—This is a general formula, taking into account beams having steel on the compressive side and also the tensile strength of concrete if desired. It is based on the moment of inertia of the steel and of the concrete beam, and can readily be derived for our special case where there is no tension carried by the concrete, and no steel on the compressive side of the beam.

A triangular stress diagram is assumed.

Using the notation employed in our general discussion, we have

$$y_1 = -\frac{Se}{b} + \sqrt{2\,Sed + \left(\frac{Se}{b}\right)}$$

Then the moments of inertia of the steel and concrete about the neutral axis are, respectively,

$I_S = S\,y_2^2$ and $I_C = \frac{1}{3}\,b\,y_1^3$;
then $T = \frac{1}{2}\,M_O \div I_S/y_2$,
$C = \frac{1}{2}\,M_O \div I_C/y_1$,
$M_O = 2I_S\,T/y_2 = 2I_C C/y_1$,

which three equations suffice for solving the problem.

Von Emperger's Formula.—Dr. F. von Emperger takes all tensile stresses as being carried by the steel, and the tensile stress for a maximum load as equal to the ultimate strength of the metal.

His formula differs from the previous ones, in assuming "that the compressive and tensile stresses are uniformly distributed over their respective sections."

Using the notation previously employed, his equations become as follows: Let $p = S/bd =$ ratio of steel to total section, and the other symbols remain as before. Then for rectilinear variation of the compressive stress we should have $y_1 = -15\,d\,p + d\,\sqrt{[15\,p\,(15\,p + 2)]}$ if $e = 15$.

This formula is used by Dr. von Emperger as a "close approximation," although the stress is taken as uniformly distributed in his assumption, and not as varying.

The moment of resistance will then be:

$$M_O = p\,b\,d\,T\,(d - \tfrac{1}{2}\,y_1)$$

$$= \tfrac{1}{2}bd^2\,p\,[2 + 15\,p - \sqrt{(15\,p\,[15\,p + 2])}]\,T.$$

Let $W = bd^2/6$, which is the section modulus of resistance of a concrete beam of width b and depth d,

and $C_S = 3\,p\,[2 + 15\,p - \sqrt{(15\,p\,[15\,p + 2])}]$

a constant depending entirely on the percentage of reinforcing metal and $T =$ tensile stress in the steel.

We can then write:

$$M_O = W\,C_S\,T.$$

Wentworth's Formula.—This has been adopted by the Bureau of Yards and Docks of the United States Navy and is as follows:

The tension is entirely carried by the steel and the compressive stress diagram is triangular.

If, furthermore, $A_S =$ area of steel per foot of width of beam $= 12\,S/b$, and $r = T/C$, the previous notation for other quantities being retained, then for a beam 12 in. wide,

$T\,A_S = 12\,Cy_1/2$
$A_S = 6\,Cy_1/T = 6\,y_1/r$
$T \div (d - y_1) = C\,E_S/y_1\,E_C = C_e/y_1$
$y_1 \div (d - y_1) = e/r$
$y_1/d = e/(r + e)$
$M_O = 6\,C\,y_1\,(d - \frac{1}{3}\,y_1)$ in inch-pounds.

Hennebique's Formula.—As Mr. Hennebique has done a very large amount of work all over the world, the method used by him is of interest. It is, however, theoretically open to criticism, Mr. Goldmark states. He assumes that there is no tension on the concrete and also that the moment of the tensile stresses about the neutral axis equals the moment of the compressive stresses. He further assumes that the compressive stress is uniform over the compressed area. The last two assumptions are, of course, wrong, but if the average allowable stress is taken low enough, so that the stress on the outer fibre does not become excessive, the practical results are satisfactory.

He takes this uniform compression equal to 350 lb. per square inch, which for a triangular stress diagram would give 700 lb. as the maximum stress. The working stress in the steel is 14,000 lb. per square inch.

Hence, by his assumptions:

$\frac{1}{2}\,M_O = 350\,by_1 \times y_1/2 = 350\,by_1^2/2$,
or $M_O = 350\,by_1^2$
and $y_1 = 0.053\,\sqrt{m/b}$;
similarly $\frac{1}{2}\,M = S\,T\,y_2 = S\,T\,y_1$

as his assumptions of the quality of the tensile and compressive moments about the neutral axis makes $y_1 = y_2$.

From the last equation, if $T = 14{,}000$,

$$S = M \div 28{,}000\,y_1.$$

In the methods so far given, the concrete was not assumed as carrying any tensile stresses. In the next three formulas the concrete is taken as carrying part of the tensile stresses.

Considere's Formula.—This eminent investigator considers the concrete as carrying part of the tensile stresses, and assumes them uniformly distributed over the concrete below the neutral axis. The compressive stress he takes as varying uniformly between the neutral axis and the extreme fibre.

Let $h =$ depth of beam, b its width, $h_x =$ distance from lower surface to neutral axis, $h_u =$ distance from lower surface to steel reinforcement, $p =$ area of steel $\div$ cross-section of beam $= S \div bh$, and $t =$ max. tensile stress on concrete. Then equation (3) in the general solution takes the form

$$\frac{h\,(1 - x)}{h\,(x - u)} = \frac{C/E_C}{T/E_S},$$

$$\text{or } C = \frac{T}{e}\;\frac{(1 - x)}{(x - u)}.$$

Equating tensile and compressive stresses,

$$t\,b\,h\,x + T\,b\,p\,h = \tfrac{1}{2}\,C\,b\,h\,(1 - x);$$

substituting the value of C above,

$$t\,x = T\,p = \frac{T\,(1 - x)^2}{2\,e\,(x - u)}.$$

Finally, taking moments about the centroid of compressive forces,

$$M_O = T\,p\,b\,h\ [2/3\,h\ (1-x) + h\ (x-u)] + t\,b\,h\,x\ [2/3\,h\ (1-x) + 1/2\,h\,x]$$

$$= b\,h^2 \left(t\,x\,\frac{4x}{6} + T\,p\,\frac{x-3u+2}{3} \right)$$

M. Considère takes T = elastic limit of the steel and t equal to the stress which will extend the concrete 0.015 to 0.020 per cent., i. e., from 171 to 427 lb. per square inch, according to the grade of concrete used.

Johnson's Formula.—This formula has been quite widely used. It assumes part of the tension as carried by the concrete and uniformly distributed. As to the compression, the assumed curve is such that $P_c = 5/8\,C\,b\,y_1$ and $y_3 = 2/3\,y_1$.

The modulus of concrete is taken as $2/3\,E_c$ for rock concrete, and for cinder concrete $= 1/2\,E_c$.

The tensile stress acting on the extreme edge of the concrete beam is taken equal to eight-tenths of t, the tensile strength of concrete. This last assumption is in accordance with Considère's experiments.

If, further, P_t = total tensile stress carried by concrete, then $P_c = S\,T + P_t$, or, $5/8\,C\,by_1 = S\,T + 8/10\,t\,by_2$.

But as $y_2 = 2/3\,y_1\,T\,E_c/C\,E_s$ (A)

$$5/8\,C\,by_1 = S\,T + 8/15\,\frac{T\,E_c\ t\,by_1}{C\,E_s}$$

$$S = \frac{15\,C\,by_1 - 64\,t\,by_1\,(T\,E_c/C\,E_s)}{120\,T} \qquad \text{(B)}$$

$$\text{and}\quad M_O = S\,T\left(y_2 + \frac{2y_1}{3}\right) +$$

$$8/10\,t\,by_2\left(\frac{y_2}{2} + \frac{2y_1}{3}\right) \qquad \text{(C)}$$

Hatt's Formula.—Prof. W. K. Hatt has developed some formulas that may be stated as follows: He assumes the tensile stress as partly carried by the concrete, the distribution, both for the tensile and compressive stresses being given by a parabola with axis horizontal and its origin on the outer edge.

Let E_t = modulus of concrete in tension, $l = E_c/E_t$, $q = E_s/E_t$, p = ratio of steel area to total cross-section of beam, l_3 = extension of concrete on extreme element per unit of length.

$$\text{Then}\ \frac{l_1}{l_3} = \frac{C/E_c}{t/E_t} = \frac{h\,x}{h(1-x)}\ \text{or}\ C = \frac{t\,l\,x}{1-x}$$

$$\text{and}\ \frac{l_2}{l_3} = \frac{T/E_s}{t/E_t} = \frac{h(u-x)}{h(1-x)}\ \text{or}\ T = \frac{t\,q\,(u-x)}{1-x}$$

Equating the tensile and compressive stresses,

$$2/3\,C\,by_1 = 2/3\,t\,bh\,(1-x) + p\,bh\,T$$

$$\text{or,}\ 2/3\,C\,x = 2/3\,t\,(1-x) + p\,T.$$

Inserting values of C and T given above,

$$2/3\,t\,\frac{l\,x^2}{1-x} = 2/3\,t\,(1-x) + p\,t\,q\,\frac{(u-x)}{(1-x)}$$

$$x = \frac{\dfrac{4+3pq}{2} + \sqrt{4l + {}^9/_4\,p^2q^2 + p[6q(u[l-1]+1)]}}{2\,(b-1)}$$

Having solved x, C and T may be computed from the first two equations.

Taking moments about the neutral axis we have

$$M_O\left[{}^5/_{12}(1-x)2 + {}^5/_{12}\,\frac{l\,x^3}{1-x} + pq\left(\frac{u-x}{(1-x)}\right)^2\right]t\,bh^2$$

or if the expression in brackets is called K,

$$M_O = K\ t\,bh^2$$

Professor Hatt replaces the above complicated form by a closely approximate straight line formula:

If P = percentage of steel $= 100\,p$, then for 1:2:4 stone concrete

$$K = [1/3 + ({}^7/_4\,u - 1)P],$$

or if $u = 7/8$

$$K = (0.33 + 0.53\,P),$$

which for $t = 240$, gives

$$M_O = (127P + 80)\ bh^2 = (165P + 104)\,bd^2$$

For 1:5 gravel concrete the corresponding expressions are:

$$M_O = (180P + 80)\ bh^2 = (234P + 104)\ bd^2.$$

The above expressions include tension in concrete, hence they give the bending moment at the "first crack."

The stresses after the concrete ceases to act on the tension side may readily be obtained by omitting the tensile stresses. The equation for M_O then becomes:

$$M_O = bh^2\ [{}^5/_{12}\ cx^2 + p\,T\ (u-x)]$$

Condron's Formula.—Mr. T. L. Condron has lately made a study of 202 tests of concrete steel beams, which have been made in different laboratories in the United States within the last few years. As the result of this comparison, Mr. Condron suggests the following expression for the bending moments at breaking loads:

For corrugated bars:

$$M_O = (450P + 55)\ bd^2$$

and for plain bars:

$$M_O = (275P + 55)\ bd^2$$

He further suggests a general empirical formula for steel, having an elastic limit of 60,000 lb. per square inch.

$$M_O = T\,bd^2\ (500P + 50) \div 60{,}000,$$

$$\text{or}\quad M_O = T\ bd^2\ (P + 0.1) \div 120.$$

$$\text{whence}\ d = \sqrt{120\,M_O\ (P + 0.1) \div T\,b}$$

$$S = 1.2\,M_O/Td - bd/1{,}000.$$

Talbot's Formula.—Prof. A. N. Talbot, of the University of Illinois, as the result of an elaborate series of experiments, has prepared the following simple formula:

$$M_O = S\,T\ (0.906 - 6.5\,p)\ d,$$

in which $p = S/db$.

Taking P = percentage of steel $= 100\,p$, and T = 15,000 lb. per square inch, then for a width of 12 in. and working loads,

$$M_O/d^2 = 1{,}800P\ (0.906 - 0.065P).$$

This equation gives a flat curve, which agrees closely with the straight line as given by Mr. Condron.

Goldmark Formula.—Mr. Goldmark has found the following a simple method for computations. The formulas are similar in form to those given in Taylor and Thompson's treatise on concrete: The assumptions are that all tension is carried by steel and that the compressive stress curve is the one given by Capt. Sewall, so that its area is equal to 5/8 of the maximum fibre stress multiplied by the area in compression and the distance of its centroid from the top is 2/5 of the distance from the top to the neutral axis.

Let p = cross-section of steel ÷ cross-section of beam above center of steel, and x = distance from top to neutral axis ÷ distance from top to center of steel.

Then, from the general discussion, we readily deduce the following equations:

$$x = \frac{1}{1 + \dfrac{T}{Ce}} = \sqrt{4/5\,ep\ (4/5\,ep + 2)} - 4/5\,ep \qquad \text{(A)}$$

$$\frac{T}{C} = \frac{e(1-x)}{x} \qquad \text{(B)}$$

$$p = \frac{5}{8\,\dfrac{T}{C}\left(1 + \dfrac{T}{Ce}\right)} \qquad \text{(C)}$$

$$M_O = 5/8\,C\,bd^2\ (1 - 2/5\,x) = p\,T\,bd^2\ (1 - 2/5\,x) \qquad \text{(D)}$$

Itemized Cost of Hand-Mixed Concrete Work.

Mr. Fred. R. Charles, city engineer of Richmond, Ind., has compiled the following notes concerning the cost of five pieces of hand-mixed concrete work done by day labor under his charge as engineer and superintendent of construction.

The first work was the construction of an abutment and six river piers for a bridge over the Miami River at Fernald, O. The piers were put down with cofferdams. Sand and stone were secured close to the site, but the cement had to be teamed 10 miles. The concrete amounted to 1,542 cu. yd., and cost $6.30 a yard, made up as follows: Cement at $2.10 per barrel, $1.58; sand, 35 cents; stone, 75 cents; lumber, 64 cents; tools, 20 cents; total for materials, $3.52; pumping, 15 cents; labor at $1.75, $2.78.

The second work was the construction of two abutments, measuring 434 cu. yd., for the Ernst St. viaduct in Cincinnati. The cost per cu. yd. was $6.08, itemized as follows: Cement, at $1.70, $1.48; sand, 64 cents; stone, $1; lumber, 40 cents; tools, 6 cents; total for materials, $3.58; excavating in rock and shale, $1.12; mixing and placing concrete, $1.13; building forms, 25 cents. Labor was paid $1.75 a day.

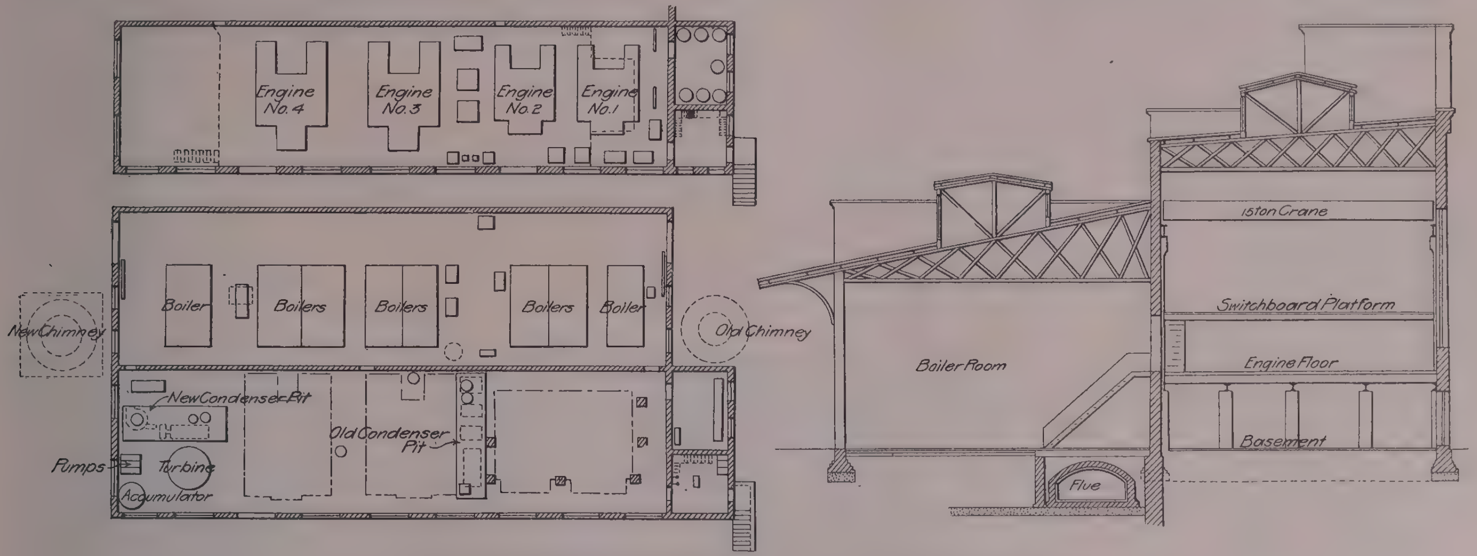
The third work was the construction of 570 cu. yd. of concrete in the pedestals of the Quebec Ave. viaduct at Cincinnati. These measured 5 ft. square on top and were from 8 to 20 ft. high. Their location was very inconvenient for the delivery of materials, which was wholly team and wheelbarrow work. The total cost was $7.16 per cu. yd., itemized as follows: Cement, at $1.60 a barrel, $1.40; sand, 53 cents; stone, $1.84; lumber, 38 cents; tools, 5 cents; total for materials, $4.20; labor at $1.75 a day, $2.96.

The fourth work was a pier, two abutments and some pedestals for a railroad viaduct in Cincinnati. The pier was 56 ft. high and a steam derrick was used in handling the concrete for it. On the remainder of the work all materials were teamed or wheeled. The total amount of concrete was 2,111 cu. yd., and its cost was $7.23 per cu. yd., itemized as follows: Cement at $1.60, $1.44; sand, 50 cents; stone, $1.03; lumber, 54 cents; tools, 25 cents; water, 3 cents; total for materials, $3.79; labor at $1.75 a day, $3.44.

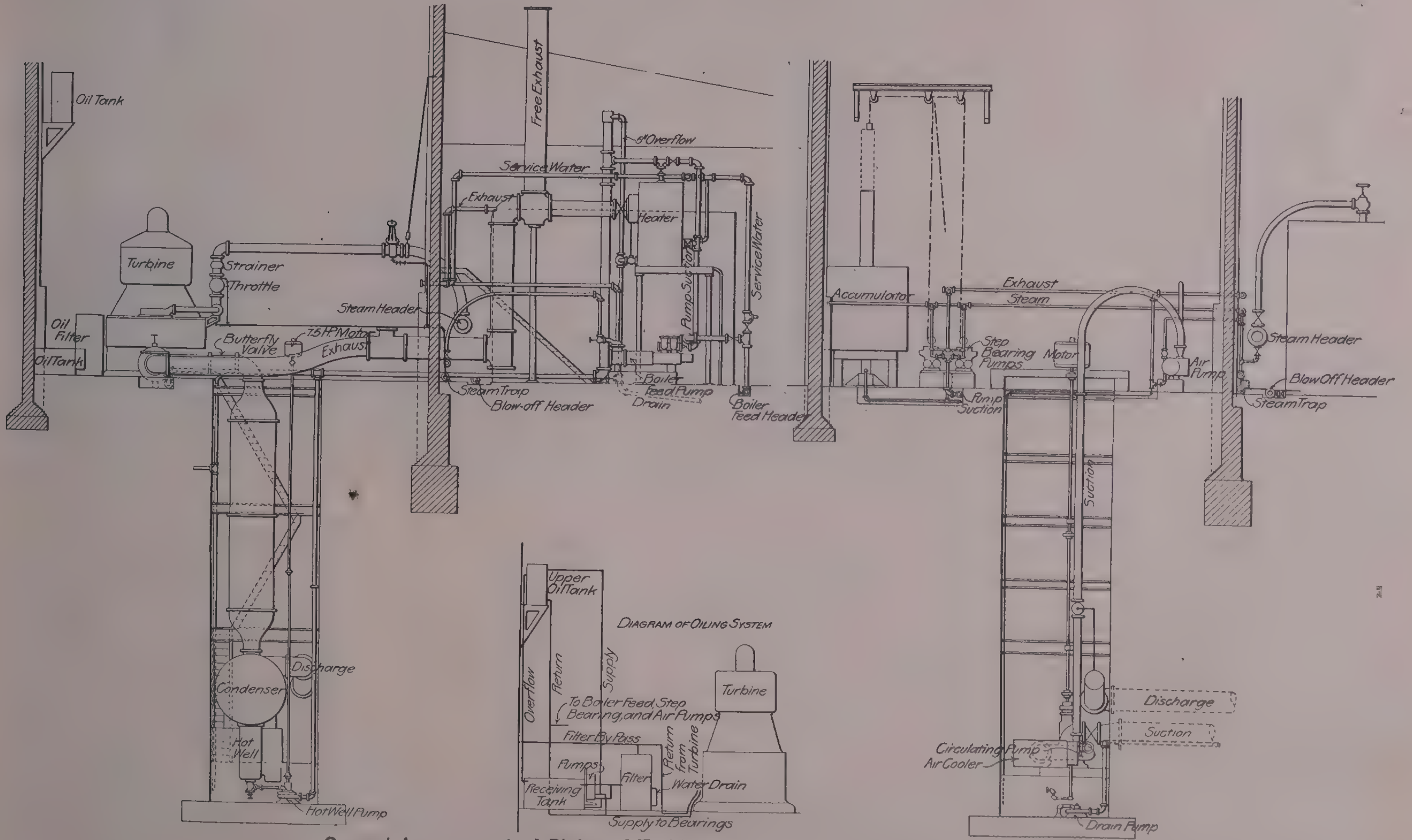
The last work was a reinforced concrete dam across the Whitewater River at Richmond, Ind. It measured 220 cu. yd. The footings were put in with the help of cofferdams and steam pumps. The cost was $5.58, itemized as follows: Cement at $1.60, $1.485; sand and gravel, 80 cents; lumber, 60.8 cents; tools, 44.5 cents; total for materials, $3.338; clearing and excavating, 96 cents; setting forms and mixing concrete, $1.007; pumping, 27.5 cents.

The Power Station of the Houston Lighting and Power Company.

The power station of the Houston Lighting & Power Co., of Houston, Tex., has been in course of construction ever since 1900, when the oldest portion of it was put in service. This section contained two 300-kw. generating units and three 350-h.-p. boilers, and from this beginning it has developed until its units have a total rating of 3,300 kw. and its boilers 4,250 h.-p. Current is supplied over 600 miles of line wires to 1,600 h.-p. in small motors, 50,000 incandescent lamps and 2,200 arc lights. The company's properties are now being overhauled by Messrs. Ford, Bacon & Davis, of New York, and the station as reconstructed is interesting for its general arrangement, condensing plant details, and use of fuel oil.



Floor Plans and Cross-Sectional Elevation of Houston Central Station.



General Arrangement of Piping of Turbine and Condenser, Houston Central Station.

The station is located on a high bluff rising from a fresh-water bayou; the floor of the engine room is about 50 ft. above the water level of the bayou and advantage is taken of the unusual topographical details to arrange the condensing plant in a special manner. The present power house is a two-story 172x42-ft. brick building, with 155x44-ft. boiler room extension. The engine room is two stories high, with a three-story and attic tower. The boiler room is one story high, with open loft. The engine room floor and roof are structural steel framework, the roof being covered with porous tile and composition. The roof of the boiler room is corrugated iron. All walls except the partition wall between the engine and boiler rooms are 17 in. thick. The partition wall is 13 in. thick. The entire front of the building is faced with buff brick with stone window-sills and belt courses and terra cotta coping.

There are two 300-kw. General Electric alternators each direct-connected to a McIntosh-Seymour horizontal cross-compound condensing engine with 14x28x32-in. cylinders, each rated at 500 h.-p.; and two 600-kw. General Electric alternators each direct-connected to a Rice & Sargent horizontal cross-compound condensing engine having 18x36x42-in. cylinders and rated at 1,000 h.-p. each. These four units are located in the older portion of the station, and up to a year ago were sufficient to carry the load satisfactorily. During 1905 the engine and boiler rooms were extended and the generating apparatus was increased by the addition of a Curtis vertical turbo-alternator; a 1,500-kw., 900 r.p.m., 2,300-volts, 377 amps, 8-pole unit, said to be the first turbine turned out at the Lynn plant of the General Electric Co. The addition of this unit at the Houston power station required a complete new installation of condensers, condenser pit and auxiliary apparatus, the work involving a number of unusual and noteworthy features. The turbine installation includes a counter-weight accumulator for feeding water supply to the step bearings of the turbine; two 7½x2x6-in. duplex plunger pattern Worthington pumps for pumping the water used in the step bearings; and one oil set consisting of two 2x1⅛x2¾-in. duplex pumps and tanks for furnishing lubricating oil to the turbine.

The boiler room equipment consists of three 350-h.-p. Cahall boilers and two 350-h.-p. and three 500-h.-p. Babcock & Wilcox boilers. All are fitted to burn oil as fuel. The three boiler units last mentioned were installed to serve the turbine set. They are fitted with internal superheaters and deliver steam at 200 lb. pressure. The other boiler units supply the reciprocating engines and deliver steam at 140 lb.

Water from a 1,200-ft. natural-flow artesian well is used for water feeding. It is forced to the boilers by a 10x6x10-in. horizontal duplex pressure pattern Worthington feed pump, three 10x7x10-in. duplex Blake feed pumps, and one 5½x3x6-in. duplex Blake feed pump. There is a Webster vacuum feed-water purifier and filter and a 1,000-h.-p. vertical open heater made by the Platt Iron Works Co.

The auxiliary electrical apparatus at the station includes three motor-driven exciter sets, each consisting of a 25-kw. generator coupled direct to a 37-h.-p. 220-volt induction motor. These exciter sets are used for starting the generating units when current is available. For starting after a complete shut-down, there is an auxiliary exciter set consisting of a 30-kw. generator driven by an 11x8-in. vertical marine type engine.

The engine room is spanned by a 15-ton hand power overhead traveling crane having 37-ft. 9-in. span and a lift of 17 ft. The crane was furnished by the Wellman-Seaver-Morgan Co., of Cleveland.

As the base of the turbine is approximately 50 ft. above the average water level in the Buffalo Bayou, from which condensing water is taken, it was thought best to place the condenser in a deep pit rather than attempt to lift the circulating water so high. Accordingly all the apparatus pertaining directly to the condensing system is located at the bottom of a pit, approximately 10 ft. square and 43 ft. deep measured from the base of the turbine. The pit was constructed of steel I-beams and concrete reinforced with expanded metal in the sides. The turbine condenser, which is of the Worthington surface type rated at about 6,000 sq. ft., is supported near the bottom of the pit, and the exhaust from the turbine reaches the condenser through a 48-in. cast iron pipe. Immediately below the condenser and forming part of it is a square cast-iron box which receives the condensed water.

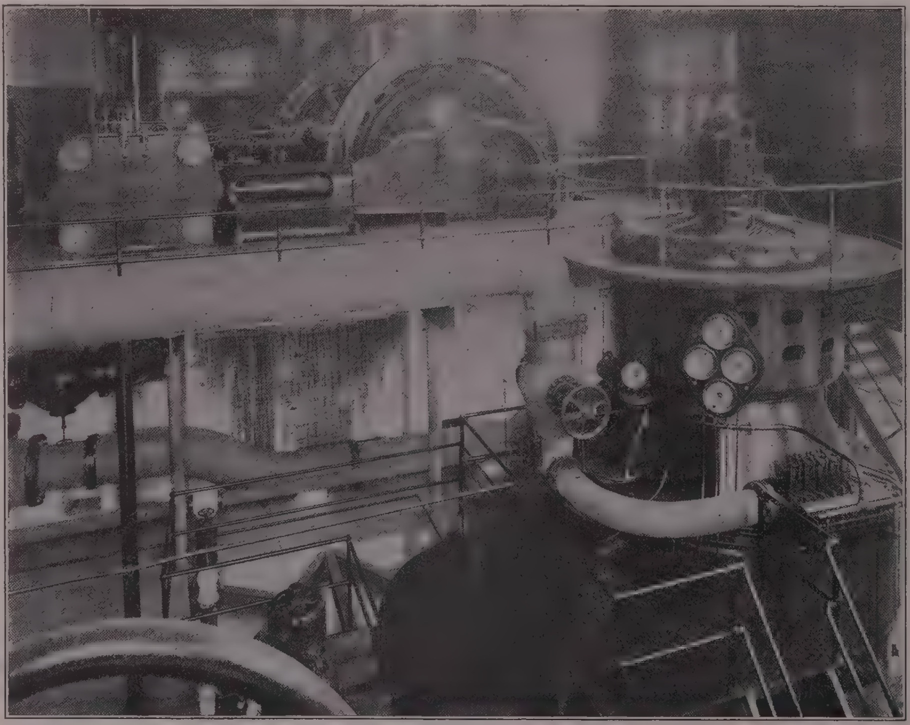
The circulating water for the condenser is taken from the bayou through a 16-in. suction pipe, passes through an air cooler located on the end of the condenser, into the bottom of the condenser, through the condenser and back to the bayou through a 24-in. discharge pipe. The intake and discharge mains are carried on cradles inside a brick tunnel about 100 ft. long, extending from the power station building on the bank of the bayou. The water is circulated by a 16-in. Worthington centrifugal pump driven by a 50-h.-p., 220-volt, three-phase induction motor. In order to keep the motor dry, it is located at the level of the top of the condenser pit and drives the pump through a vertical shaft. The vapor is drawn from the condenser through the air cooler by a steam-driven 8x16-12-in. single horizontal rotative dry vacuum Worthington pump of the center crank pattern.

For lifting the water from the hot well there is a 3-in. two-stage centrifugal pump at the bottom of the pit driven through a vertical shaft by a 7½-h.-p. induction motor at the top of the pit. This pump delivers the water to the feed-water heater.

In order to prevent the possibility of seepage water accumulating in the condenser pit, a 2½-in. vertical volute Worthington pump is provided at the bottom of the pit. This pump is driven through a vertical shaft by a 5-h.-p. induction motor located at the top of the pit.

The station log at this plant shows the following averages: Vacuum, 27.6 in.; temperature of hot well, 84° F.; temperature of condenser injection water, 76° F.; temperature of discharge water, 70° F.; temperature of feed water, 138° F.

The condensing apparatus for the reciprocating engine units is located in a separate condenser pit, 34 ft. deep, under the old portion of the plant. The apparatus comprises two 9x20x12-in. jet condensers with vertical twin vacuum air-pump; one 12x28x18-in. jet condenser with similar pump; and one 16x40x21-in. jet condenser also served by the same type of air pump. These condensers and pumps were furnished by the George F. Blake Mfg. Co. Circulating water for this group of condensers is taken from, and discharged into, the bayou through mains laid in a tunnel in about the same way as described for the turbine condensers.



View of Turbine and Reciprocating Engine Units.

The station is now burning exclusively a good grade of Texas oil as fuel under the boilers. The oil is received in tank cars from which it is unloaded by gravity into three storage tanks, each of 1,200-gal. capacity. These tanks are housed in a brick vault outside the station. From them the oil is forced directly to the burners at 40-lb. pressure. For this purpose there are two complete oil-pumping systems, one consisting of two 3x2x3-in. Snow duplex pumps and receiving tank, and the other consisting of two 4x2¾x4-in. Snow duplex pumps and receiving tank. Both of these oil pumping outfits were furnished by the National Supply Co., of Chicago.

The oil burners under the boilers consist of double nozzles in which the oil as it comes through, drop by drop, is caught up by a jet of live steam which serves to atomize the particles and force them to the burners in a fine spray. Provision is made for supplying the burners with superheated steam taken from a separate superheater made by running the steam supply pipe through the furnace before it reaches the burners.

The station is now using about 150 barrels of oil per day, there being 42 gal. of oil to a barrel. The total daily electrical output of the station averages about 45,000 kw.-hours measured at the switchboard, so that the plant is getting from 2 to 2½-kw.-hours per gallon of oil. It is usual to figure about 3.6 barrels of Texas oil as the equivalent to one ton of Indian Territory run-of-mine coal.

Road Maintenance.

Contributed by Robert A. Meeker to the Annual Report of the New Jersey Commissioner of Public Roads.

The maintenance of a road, already in good condition and of sufficient strength, if properly carried on, is almost entirely a question of wear. The rapidity of this wear varies with the nature of the rock used for the road covering, but, even with the softer rocks, there need be no deterioration if proper attention is given to maintenance. The problem is to reduce the wear, both from traffic and the weather, to a minimum by substituting other material for that worn out, and to do this in the most economical manner.

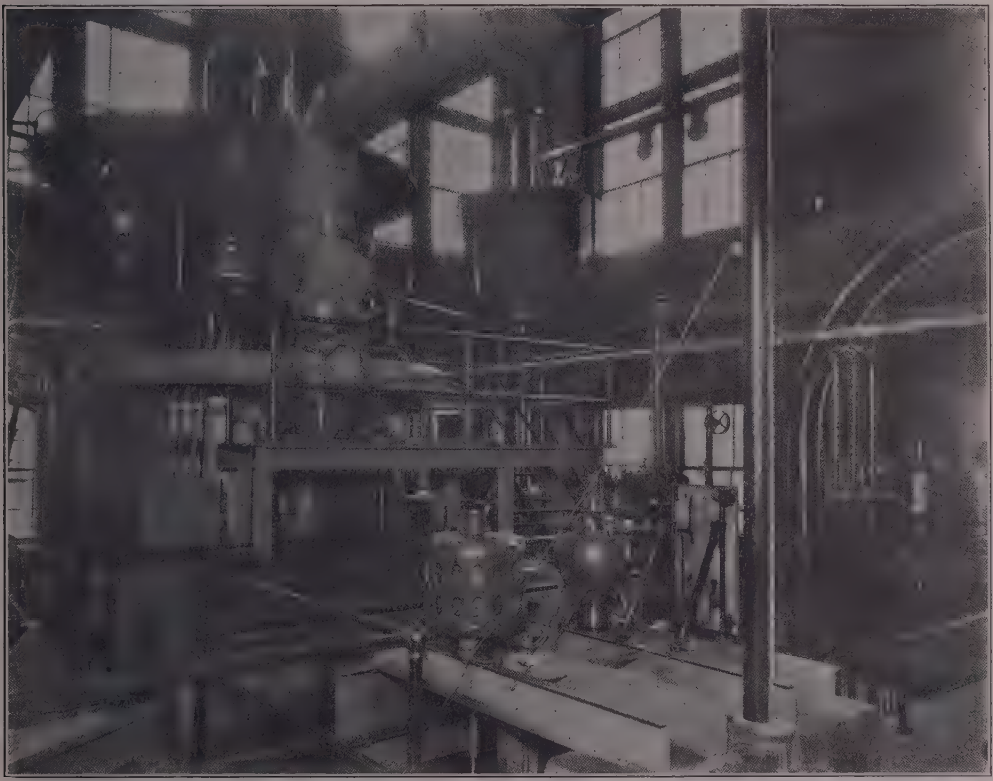
The conditions under which wear will be reduced to a minimum, under a certain traffic, are good drainage of surface and subsoil. To attain this object the material used for the surface should be hard, in order to resist the wear of the traffic, should not contain too much small stone to absorb moisture, and should be thoroughly consolidated and of sufficient depth to bear the loads to which the road is subjected, so that the wear may be confined to the surface. On very few roads are these conditions to be found, but their attainment should be kept in view, and it is certain that in proportion as they are attained will be the economy of maintenance.

Drainage almost always requires attention, and there is usually a great deal that can be done to improve it, at a slight expense, and nothing pays so well in the end. Proper care of the surface is generally all that is needed to prevent water from standing on the road or in the gutters, but a dry surface is not enough. On a flat, water may be seen standing in the ditches to within a few inches of the surface of the road, in which case both the subsoil and road coating must be softened by it and remain so long after the water in the ditch is gone. A deeper ditch, a larger culvert, or a drain cleaned out through the adjoining land is usually sufficient to remove a cause of great mischief. On a hillside, springs under the road and land water from the sides can be cut off and led away by underdrains at a trifling cost.

It is cheaper to procure good material from a distance than to try to save money by using inferior stone found along the line of the road.

The road coating may often be improved in composition and rendered harder by scraping, and a fairly good surface can be maintained at all times by proper care. With material of all sorts, the influence that a good surface has in keeping down wear is greater than might be supposed.

Everything should be done to make a road strong enough to bear the traffic without bending or cross-breaking and a reserve of strength is always desirable. Fluctuations of traffic are most trying. A road may be strong enough to bear the ordinary loads that pass over it and still be unable to support the excessive weights that may be brought upon it. When we know a road is to be subjected to heavy strains, it is always better to strengthen it by placing an extra coating upon the surface, rather than wait until the road is broken and disrupted. When a road is broken or cut by excessive weights, it is no longer a mere matter of replacing wear, but of expensive repair, and, in many cases, of entire rebuilding.



Turbine and Motors for Pumps in Condenser Well, Houston Central Station.

To replace wear that is unavoidable is a very simple matter when constant attention is given to the road. It is only when the surface is neglected for a long period that the matter of repairs becomes a serious one. A little attention to drainage, the removal of slight obstructions from the gutters, the clearing away of rubbish from the mouths of culverts, the removal of grass and brush from ditches and the careful spreading of small quantities of stone over depressions, as soon as they begin to appear, will keep a road in fine condition until it is almost entirely worn out. Nothing is more neglected than the removal of worn material from the road. It seems to be regarded merely as a clearing of the surface from mud, and, as such, an unnecessary expense, while, in reality, this worn material affects the entire composition of the road covering; consequently, unless the mud is washed away by nature from the surface, scraping or sweeping is necessary to preserve the proper proportion of solid stone in the road. Careful tests of the composition of our best road coverings have shown that from three-fourths to four-fifths of the material is solid stone, the remainder being material fine enough to be washed through a cheesecloth. Further careful tests have demonstrated that as this proportion of fine stuff is exceeded will the road be soft, easily acted upon by traffic, water and frost; in consequence, there will be an excessive waste of road material.

From the foregoing it is readily seen that the matter of road repair and maintenance is one that requires constant and careful attention. To attain the best results the most successful means so far employed is to assign a certain section to one man and hold him personally responsible for the condition of the road. It is also the most economical, because the seasons of the year when the road surface is most in need of attention are those when the farmer and laborer have least to do. The proper season for laying the bulk of the fresh materials is in the autumn and early winter, as soon as the surface of the road becomes softened by the fall rains and before the ground freezes. Materials laid at this season consolidate more quickly and become more thoroughly incorporated with the body of the road, hence are less liable to become loosened in dry weather. A thorough cleaning out of all gutters, culverts and bridges should take place in the fall, as soon as the dry weather is past. If all silt and road dirt are then removed down to the hard bottom, leaving nothing to give a hold to grass or weeds, this will, in the majority of cases, be sufficient for a general cleaning up. All ditches and side drains should be carefully cleaned out and opened, every precaution being taken to remove all water from the line of the road as soon as possible. No water should be allowed to stand in any gutter along the road, as it seriously injures the foundation. If these things are done before the ground freezes, the road will require but little work in the spring, except surfacing, and the resultant saving in material will be very great.

The Hydraulic Testing Laboratory of the Worcester Polytechnic Institute.

By Charles M. Allen, Assistant Professor of Experimental Engineering.

The main Hydraulic Testing Laboratory of the Worcester Polytechnic Institute is situated on a water privilege some twenty minutes' ride from the Institute on the Worcester & Holden electric road. The plant was installed in 1895 and is used for the purpose of instruction in connection with the regular experimental engineering laboratory and thesis work with the students, as well as for original investigations along various lines. The laboratory offers exceptional facilities for conducting a large variety of hydraulic experiments upon a scale often met with in commercial practice. The Institute owns and controls the entire privilege including a storage pond of some 400 acres. Within the past year the plant buildings have been enlarged to accommodate the installation of additional apparatus, including a large weighing tank of 50,000-lb. capacity.

The principal apparatus is located in a one-story wooden frame building with a basement, containing altogether about 4,000 sq. ft. of floor space.

Water is conducted to the plant through a 40-in. steel riveted pipe about 400 ft. in length between the head gate and the building. The pipe line has a gradual slope and is equipped with piezometer rings placed about 10 ft. from either end. The accompanying drawing (Fig. 1), shows the profile of pipe line, the location of piezometer rings, etc. A 36-in. Venturi meter is inserted in the pipe line just inside of the building giving a means of measuring the water before it passes through the turbine.

An 18-in. Hercules horizontal turbine with a 12-ft. draft tube furnishing about 80 h.-p. is available for various experimental purposes, such as power and efficiency tests. The turbine, after being carefully rated by an Alden absorption dynamometer mounted on its shaft, can be used as a transmission dynamometer to drive pumps and machines of all kinds to determine their efficiency.

The turbine discharges into the weir flume in the basement. At the lower end is located a standard 10-ft. weir with end contractions. The weir flume is 60 ft. long by 16 ft. wide with a depth of 3½ ft. below the crest of the weir. It has a smooth plank bottom and is enclosed with brick walls. There are two sets of hook-gauge tanks set flush with the brick walls and extending down to the bottom of the flume. The length of weir is adjustable from 16 ft. without end contractions to as small as desired with end contractions.

A series of experiments is now being made to ascertain the loss in head due to friction of flow through the pipe line with varying velocities, both before and after the pipe is cleaned and painted. The hook-gauge method is used to obtain this loss of head and proves very satisfactory. The annular space in the piezometer ring (see Fig. 2) is piped directly to an adjustable hook-gauge vessel. A short piece of ¾-in. rubber hose makes this flexible connection and a valve inserted in the line throttles excessive fluctuation. No air pockets are allowed, and 1-in. pipes are used up to the hose connections. The apparatus at each hook-gauge station is simple in construction, being for the most part made up of pipe fittings. The vessels are 4-in. in diameter. Fig. 4 shows the design of the apparatus and hook gauge.

Zero readings are obtained at the beginning and end of each series of tests by blanking off the pipe line and allowing the water to come to rest. This method was checked by the use of a levelling instrument and found to be reliable. The velocity of flow is varied by opening and closing the turbine gate. The turbine is blocked to give maximum discharge. The water passing through the 36-in. Venturi and over a 10-ft. standard weir is thus measured and a mean velocity of flow determined for each test. Results of this series of experiments will be published as soon as the set is complete.

A Cole-Flad pitometer is installed in this line and the readings taken during the tests will furnish accurate means for the calibration of the instrument.

The 36-in. Venturi meter above referred to has the upstream, throat and downstream piezometer rings connected with 1-in. piping to ¾-in. glass tubes located in the tower of the building. The upstream and throat rings are piped to the automatic recorder furnished with the meter. Piezometer tubes and water gauges for showing the heads on the various pieces of apparatus are also located in this tower, which rises a few feet above the level of the pond.

The Venturi meter discharges into the casing of the turbine and also into a 12-in. Union water meter. Taper blanks and rings are inserted in each line, taking the place of large valves, and are found to be very satisfactory.

The normal head on the turbine is 30 ft. and is ascertained during tests by comparing a calibrated floating tail race gauge (see Fig. 3) with the water gauge from the turbine casing.

A graduated gauge showing the turbine gate opening protrudes through a stuffing box on the casing, and a mercury gauge to show pressures at various points on the draft tube is located nearby. On one end of the turbine shaft is a revolution counter manipulated by a positive clutch drive and on the other end is the Alden absorption dynamometer. The latter consists of a cast-iron disc 28 in. in diameter by ½ in. thick, keyed to the shaft. This revolves between thin copper plates and runs in oil which automatically circulates through small pipes from circumference to hub. Water circulates under pressure between the copper discs and the outside casings. The water pressing against the copper discs causes friction and at the same time carries off the heat generated by that friction. The casing is allowed sufficient rotation to operate the automatic regulating valve, the amount of rotation being controlled by a stop adjustment applied to the arm of dynamometer.

The automatic regulating valve keeps the required loads absolutely constant during each test. The valve is made up principally of two brass tubes, one within the other. One of them is slotted longitudinally with a rectangular opening and the other with a trapezoidal opening. When one is directly over the other the valve is wide open. One tube is held from rotating by the water-supply pipe-connection, the other rotates with the casing, thereby increasing or decreasing the opening. In actual operation the opening through the valve is fixed by hand at a point sufficing to give the required pressure to balance the system. Then, as the friction between discs and copper-plates increases from any cause, the casing turns with the discs until the valve closes enough to reduce the pressure by the amount requisite for maintenance of equilibrium, and under ordinary conditions, if the speed of the discs be over 150 revolutions per minute, this takes place before the arm reaches the stop. An opposite alteration in friction secures its own equilibrium in a similar way. Gradual fluctuations of water pressure behind this valve of not over 5 or 10 lb. per square inch will not throw the system out of balance. The load on the weighing arm gives the horse power per 100 r. p. m.

Water under pressure is furnished the dynamometer by a 4-in. Gould hydraulic ram or by a small Dean triplex power pump driven by a 36-in. Pelton water wheel, both situated in the basement of the laboratory.

When running power and efficiency tests on pumps, etc., requiring the entire power of the turbine, the load absorbed by the dynamometer is reduced to a minimum by attaching a draft tube to the water exhaust, thereby creating a partial vacuum in the dynamometer and thus diminishing the friction on the revolving discs. In this way the actual power absorbed by dynamometer can be reduced to 0.3 h.-p. at 100 r. p. m.

The method of conducting efficiency and capacity tests of machines, using the turbine as a transmission dynamometer, is as follows:

The machine to be tested is belted to a pulley on the shaft of the turbine. The turbine gate is opened until the desired speed is obtained. A test is then made, taking the usual readings such as speed, gate opening, head on wheel, load on dynamometer, also the necessary readings on the machine under test. Then the turbine is stopped by means of the absorption dynamometer used as a brake without closing the gate and the belt is removed. By reducing the pressure and allowing the turbine to run, taking up the load on the dynamometer so that the conditions are exactly the same as when the machine was under test, a means of knowing the exact amount of power required to drive the machine is given by simply subtracting the former load on the dynamometer from the latter. The accuracy of this method is made possible by the fact that the gate of the turbine remains in a fixed position throughout the test. It is almost impossible to set a turbine gate twice in the same position, and unless it is in the same position during the two tests the results must vary.

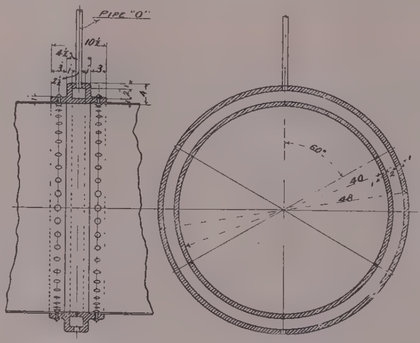


Fig. 2 Piezometer Ring.

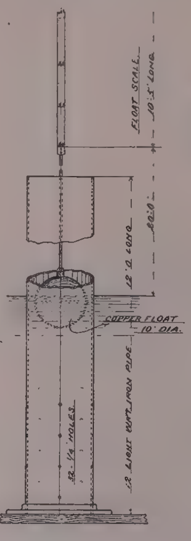


Fig. 3. Tail Water Float.

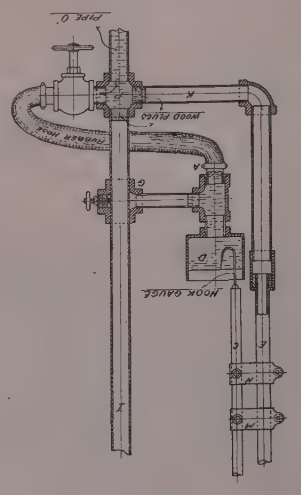
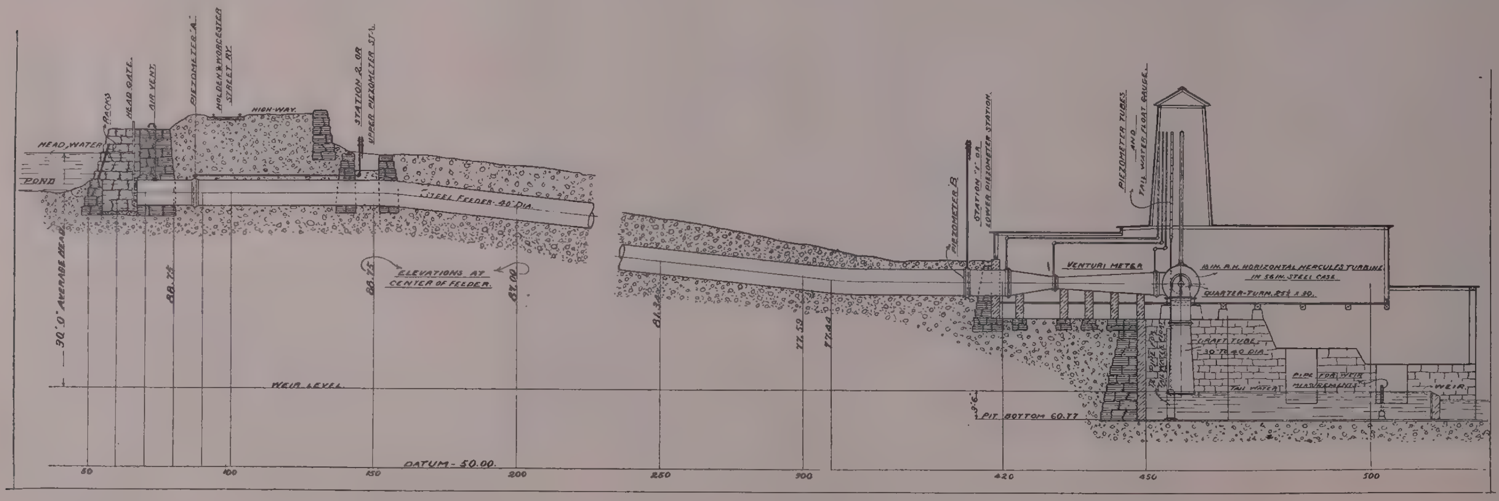


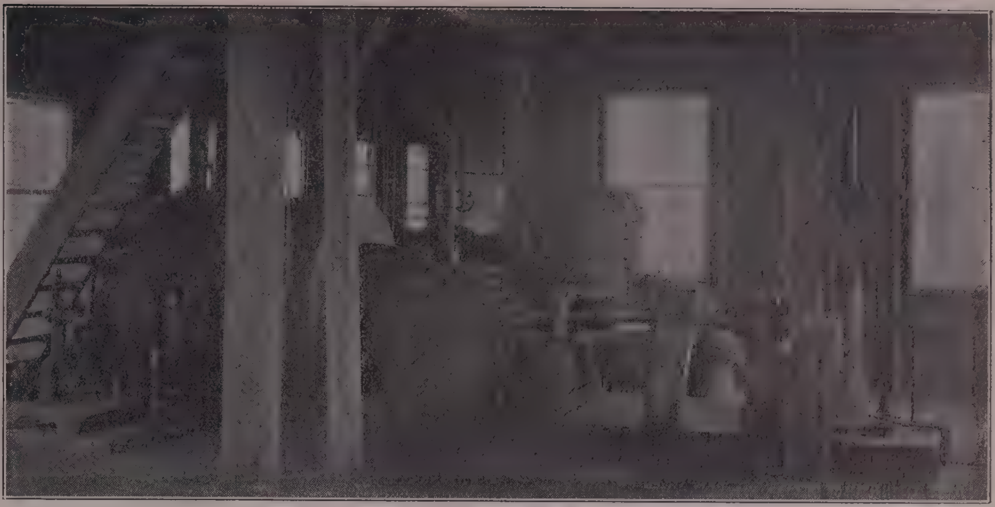
Fig. 4. Apparatus for Measuring Head.


HEAD WATER
POND
RACKS
HEAD GATE
AIR VENT
PIEZOMETER "A"
HOLDEN & WORCESTER STREET RY.
HIGH-WAY
STATION 2 OR UPPER PIEZOMETER STA.
STEEL FEEDER 40" DIA.
30'0" AVERAGE HEAD
88.75
88.75
87.00
ELEVATIONS AT CENTER OF FEEDER.
81.30
77.59
77.44
WEIR LEVEL
DATUM - 50.00.
PIEZOMETER B
STATION "1" OR LOWER PIEZOMETER STATION
PIEZOMETER TUBES AND TAIL WATER FLOAT GAUGE
VENTURI METER
HORIZONTAL HERCULES TURBINE IN 56 IN. STEEL CASE
QUARTER-TURN
DRAFT TUBE 30" TO 40" DIA.
TAIL WATER
PIPE FOR WEIR MEASUREMENTS
WEIR
PIT BOTTOM 60.77
50
100
150
200
250
300
420
450
500
Fig. 1. Longitudinal Section of the Hydraulic Testing Plant of the Worcester Polytechnic Institute.

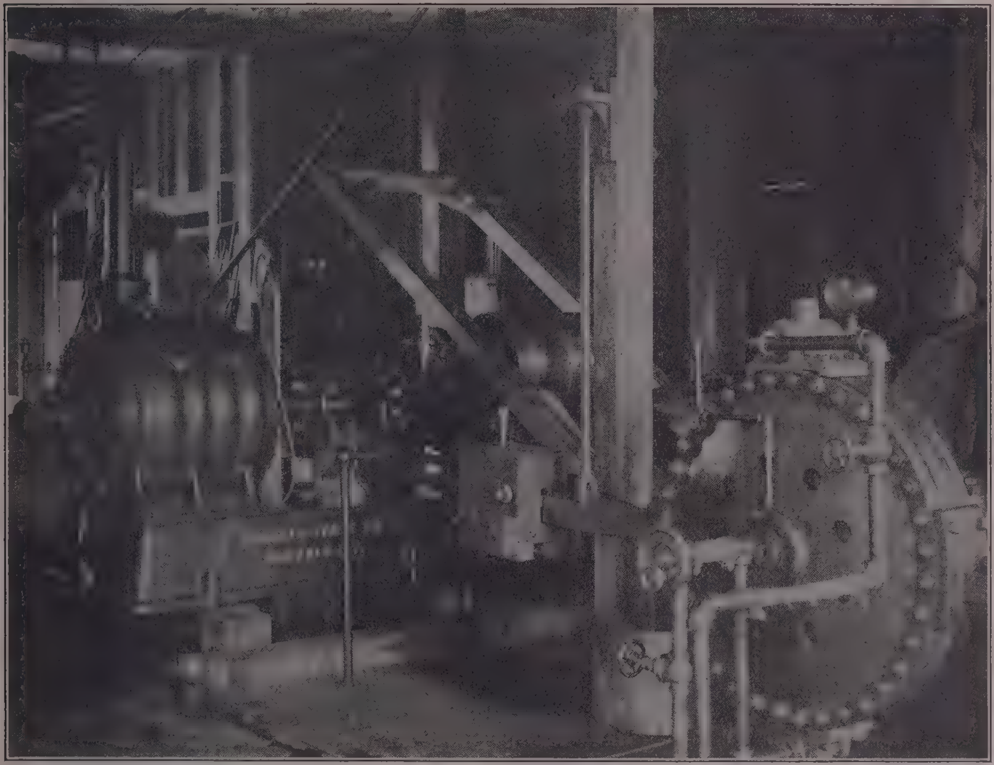
When the turbine is under test or is being used as a transmission dynamometer, its speed is controlled by either varying the gate opening by hand or by supplying the necessary loads on the absorption dynamometer.

However, there are three kinds of turbine governors at command and these are used primarily for illustrative and experimental purposes. The Snow and the Improved Lombard, built by the Holyoke Machine Co., of Worcester, and the Replogle governor, built by the Replogle Governor Works, Akron, O., make up the present installation. The unit is especially fitted for experimental work upon turbine speed regulation on account of the long penstock effect and the means of easily and quickly changing the load on the turbine from maximum to minimum, also by the effect of a fly wheel on the turbine shaft. The plant is already equipped with electricity, and arrangements have been made to install a new form of electrically controlled turbine governor.

A four-stage centrifugal pump, built by the Buffalo Forge Co., was arranged for testing in the manner described above. The discharge from the pump can either be measured in the 50,000-lb. weighing tank or by means of a standard weir in a flume situated nearby. The pump discharges into a pressure tank on which is a standard gauge which gives the head pumped against. The supply to the pump is arranged so that a negative head from 30 ft. to zero can be easily obtained by throttling. The mercury gauge connecting this line gives the actual head. There is also a pipe line connecting the main line which comes from the reservoir to the supply, which pipe gives a means for getting a positive pressure on the suction end.



Portion of Hydraulic Testing Laboratory.



Alden Dynamometer and Pump under Test.

This pump is intended to furnish water under various heads to the 36-in. Pelton wheel situated just outside of the building on a level with the basement. The normal head from the pond ordinarily operates the Pelton wheel, and it not only furnishes sufficient power to drive a small Dean triplex power pump, but also gives a means of illustrating to the students a few fundamental principles in hydraulics. For this purpose the casing of the wheel is removed and a brake applied to the rim of the pulley on the shaft, so that the speed can be varied from zero to maximum, and in this way the best speed of the buckets is shown to be about half the velocity of the water issuing from the nozzle.

The discharge from the Pelton wheel drops into a small flume, at the further end of which is a standard weir with end contractions. A small Alden absorption dynamometer is placed on the Pelton wheel shaft and in this manner power and efficiency tests can easily be made.

The low head turbine and the high head Pelton wheel furnish examples of both the Eastern and Pacific Coast types of power installations. The efficiencies of both, including the power lost in transmission, are easily obtained.

There is a set of weir flumes designed to be used in connection with calibrating the large standard weir. These flumes are 3 ft. wide, 14 ft. long, and 1 ft. below the crest of the weir and are without end contractions. The flumes are carefully calibrated by means of the large weighing tank and are then placed in parallel, all discharging into the large flume, and in this way a means is given to check the large standard weir.

A Price current meter is used for experimental purposes in determining the flow of the stream below the plant. The quantity passing a given point in the stream is known, as it has passed over the standard weir, and in this way a good check is given on the tests made by means of the current meter.

There is also installed in the plant a turbine flow recorder which automatically registers the amount of water going through the wheel both for a variable gate opening and for a variable head. The recorder was designed on the basis of the tests of the turbine at the Holyoke testing flume, and the results seem to check very closely with those found after its installation in this plant, although the conditions are somewhat different. For instance, this turbine was tested in Holyoke on a vertical shaft and under the head of about 16 ft. It is now installed in a horizontal shaft with a 12-ft. draft tube and under a head of about 30 ft., and yet the discharge as computed from the Holyoke tests does not vary at half gate more than 1 per cent., and at 0.9 and full gate about 0.3 per cent.

There are five distinct means of measuring the water passing through the plant, the pitometer in the pipe line, the Venturi meter, the turbine flow recorder which was based upon the Holyoke flume tests, the current meter situated in the weir flume, or in the stream below, and the standard weir.

Tail Race and Weir Flume, Showing Hook Gauge Tanks.

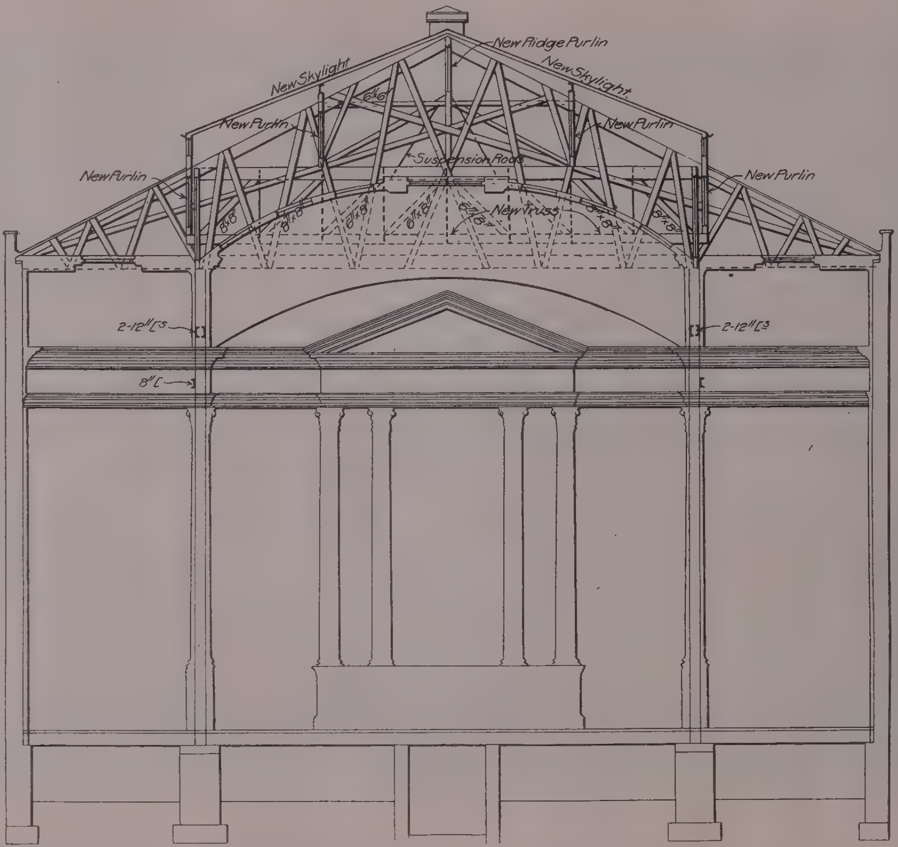
Difficult Reconstruction of a Church Roof.

The Reformed-Church-on-the-Heights at Pierrepont St. and Monroe Place, Brooklyn, is an L-shaped structure about 96x125 ft. in extreme dimensions, and has stone walls and a wooden roof. The main wing 70 ft. wide has a double-pitched roof supported on exterior walls and on interior columns in two longitudinal rows about 38 ft. apart. At the front of the building the columns are about 13 ft. apart in the rows and carry ordinary wooden triangular roof trusses with the top chords in the planes of the rafters. These trusses carry longitudinal purlins supporting the intermediate rafters. Near the center of the building the spacing of the columns in the longitudinal rows is increased to make one panel about 38 ft. long, with the columns occupying the corners of an unobstructed rectangular floor space and supporting longitudinal and transverse wooden trusses which sustain a domed plaster ceiling and a portion of the roof. This portion of the roof was uniform with that adjacent to it and was pierced with a large number of irregularly arranged small skylights set nearly flush with its inclined surface.

The transverse roof trusses were of very simple construction, consisting, as shown in the general cross-section, of horizontal bottom chords and inclined top chords connected by zig-zag web members, all of wood. The bottom chords were single unspliced full-length timbers and the web members were light planks spiked to the opposite vertical faces of both top and bottom chords. None of the members were framed except for the connections of the top and bottom chords at the ends of the truss, all other connections being made with spikes and nails and no bolts, iron ties or other metal connections being used. This obviously made weak trusses with details failing to develop the strength of the members connected. Structurally the trusses were supported only at their ends, thus having clear spans of about 65 ft., but actually the intermediate support of the bottom chords on top of the intermediate columns made them act as three-span, continuous girders. The longitudinal or purlin trusses supporting the dome and that portion of the roof above it were 6 ft. in depth and consisted of parallel chords with a double triangular system of web members. They were of an extremely light construction and, as in the main trusses, all connections were spiked or nailed.

The domed ceiling is a segment of a spherical surface with a chord of about 38 ft. and a rise of about 7 ft. It is constructed of laths and plaster, carried by a framework of 7/8-in. scarf boards in vertical radial planes which were suspended by an irregular arrangement of vertical wooden strips nailed to them and to the roof trusses and purlins overhead in any convenient positions.

This construction, although crude and imperfect, endured the test of service for many years, and until radical changes were made in the original design of the building. The most important of these was the elaborate decoration of the interior which included a great deal of art work and gilding on the domed ceiling and placing there a large amount of heavy stained glass of an estimated aggregate weight of more than one ton. This seriously overstrained the imperfect trusses and the framework was farther weakened by the removal of the interior galleries, which, acting as braces to the slender columns, had decreased their unsupported height from about 38 to 20 ft. These changes, together with the natural deterioration and decay of materials, very much impaired the stability of the building, as was evident in the serious settlement of the roof and in the 6-in. deflection of one of the purlin trusses.



Section through Church Auditorium and Dome, Showing New Trusses and Old Rafters.

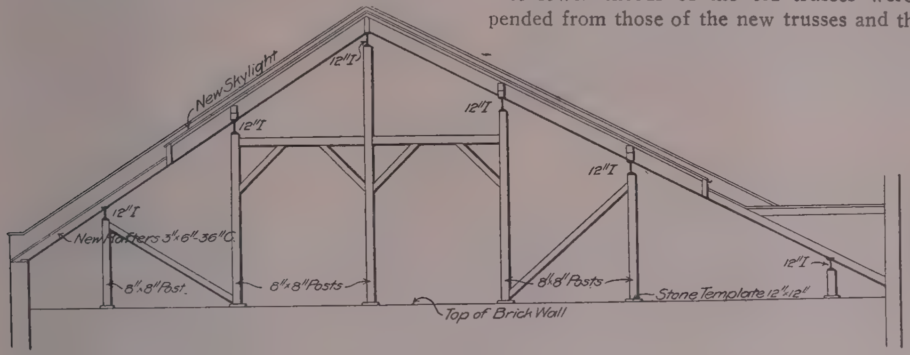
When, therefore, the collapse of the Fleet St. church in Brooklyn led to the inspection of other churches this one was condemned by the Bureau of Buildings, and was temporarily closed for repairs. It was examined by various architects and contractors who agreed that the repairs would be extremely difficult and expensive, most of them saying that it would be necessary to tear out all the interior of the church and rebuild it, thus destroying the beautiful and costly decorations for which the edifice is famous and which are considered second to few in this vicinity. It was believed by some builders that repairs short of entire reconstruction were impossible and by others that their cost would be from $30,000 to $35,000. Finally the direction of the work was undertaken by Mr. Arthur Francis Buys and Mr. Frank H. Hutton, architects, and Mr. Stephen Francis Voorhees, engineer, New York, who designed and supervised repairs that have just been successfully completed at a cost of about $10,000, without in any degree injuring the decorations or interfering with or defacing the auditorium.

When a thorough examination was made before commencing the new work it was found that the old roof of the auditorium was in very bad condition; that the dome columns were badly deflected and were, therefore, weaker than had been apparent, that the main roof trusses were badly buckled and that the 25x65-ft. roof over the Sunday school room was in even worse condition than that in the main auditorium. This roof had several flat skylights and was carried on light wooden rafters supported on thin wooden purlins. The whole framework was braced in an irregular and inefficient manner, some connections being even tied together with pieces of rope and the whole construction lacking greatly in rigidity and stability, the little that it possessed being largely due to the roof sheathing.

The first step in the reconstruction was to support the old rafters of the Sunday school roof and line them up on new transverse 12-in. I-beam purlins about 9 ft. apart, which rested at one extremity on the end wall of the building and were supported about 7 ft. from the opposite ends on the transverse partition wall separating the Sunday school room and auditorium. The projecting ends of these horizontal beams form cantilever supports for the first main roof truss over the church auditorium and terminate in its plane. The old rafters remain in position and a new intermediate one was also placed in each panel of the roof. The hanging ceiling, in which there is a large leaded glass dome light, was suspended from the new I-beams, and the small A trusses formerly carrying the ceiling were utilized to carry a working platform on which all the material for the work was hoisted through the opening of the dome light.

The most difficult part of the work, however, was the reconstruction of the church auditorium roof, especially that portion surrounding the dome. To avoid expensive shoring, with the attendant danger of damaging the decoration, it was necessary to design the new trusses so they could be erected with the old work in place. This consideration made it necessary to obtain adequate supports for the new trusses, independent of the old structure, and, as the old walls were not sufficiently strong, it was determined to reinforce the four columns at the corners of the dome rectangle and to place the entire load of the domed ceiling and the roof upon them. These columns were enclosed in richly decorated circular wooden shells which, with the bases and moulded plaster capitals, gave them a very substantial appearance. Small holes were bored through the opposite sides of the tops of the shells and from them carpenters with fine saws cut the shells neatly in half from end to end and removed them without injuring the decorations. This revealed the 10x10-in. interior columns which, instead of being solid, were found to be made of three layers of 10-in. planks, which were not even continuous, spaces being left between the ends of successive pieces. One of the columns was at least 2 in. out of plumb and all of them had been chamfered at the upper corners to clear the shells.

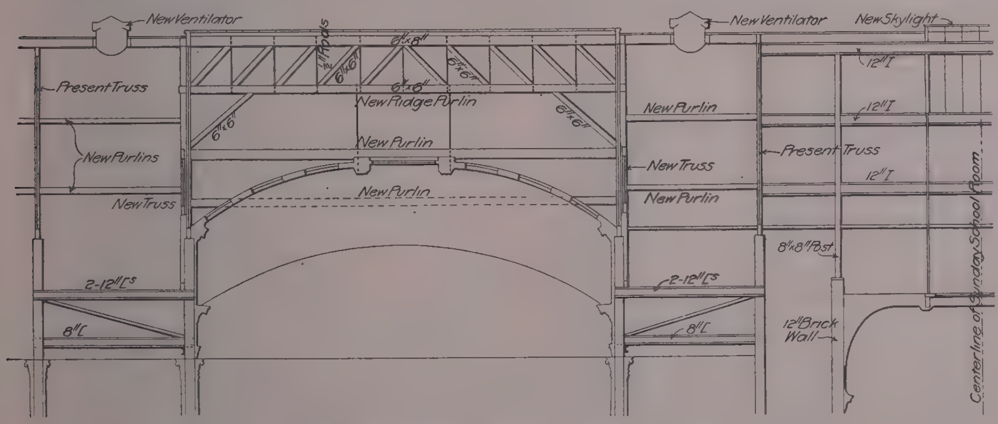
The columns, poor as they were, supported a large part of the dome weight, and it was considered a hazardous task to strengthen or remove them. The former was accomplished by cautiously cutting away from bottom to top one outside plank and substituting in its place a 10-in. channel with the back set close against the face of the wood and temporarily clamped to it. The opposite third of the wooden column was then removed and another 10-in. channel was put in its place in the same manner.



New Roof over Sunday School.

The channels were connected by top, bottom and middle riveted tie plates and by intermediate lattice bars which were bolted in position, the number of rivets used being restricted as much as possible on account of the objection to possible injurious vibrations caused by the hammering and on account of the danger from rivet forges and hot rivets among the inflammable materials of the church. As the new reinforcement channels extended above the ceiling cornice and had to enter a hole only 12 in. square, it was impossible to set them in place from the floor of the church, owing to the increased clearance necessary to permit them to assume the inclined position. A small hole was therefore cut in the floor at the base of each column and the feet of the channels were dropped into it until they had clearance to stand upright and could be moved in vertical lines to their final positions.

The wooden side pieces of the old columns were cut off square just above the tops of the reinforcing channels and the columns were each braced to the next ones in the longitudinal rows by a pair of horizontal 12-in. channels, web-bolted one on each side to their upper ends and secured by vertical connection angles and through bolts to the adjacent columns. These struts not only served to secure the columns laterally but acted as girders receiving, close to the dome columns, the ends of the vertical sub-posts supporting the new dome trusses, which were seated on shoes across their top flanges and were thus offset sufficiently from the planes of the original trusses to clear them. The new trusses were assembled in position and were connected to the old trusses by horizontal bolts through the bottom chords of both and by kneebraces engaging the tops of their end vertical posts and bolted across the webs of the horizontal longitudinal channels.

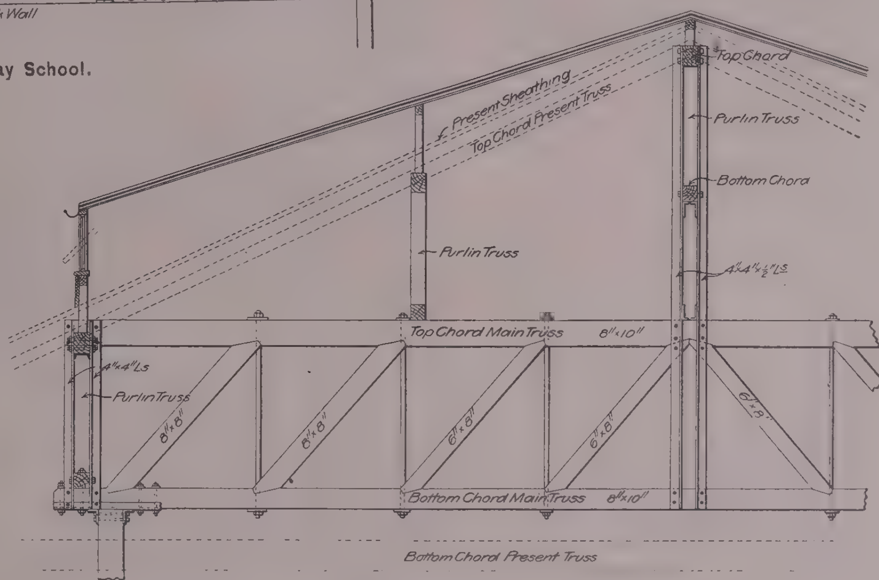


Part Longitudinal Section of Roof and Dome.

After the two main transverse trusses were completed a set of five new longitudinal trussed purlins were supported on them carrying new rafters on which the roof sheathing was wedged to accurate position and the dome ribs were suspended from them by light steel rods. A large new skylight frame or monitor of 40 ft. span with ventilating windows in the vertical sides and with long sheets of wired glass in the inclined surfaces was also built, thus affording abundant light for the dome and ventilation for the auditorium. The lower chords of the old trusses were suspended from those of the new trusses and the top chords were blocked up into line to serve as rafters. They were braced by a few of the diagonal members and the rest of the members of the old trusses were removed in order to diminish as much as possible the obstruction and the amount of inflammable material in the old attic.

The new transverse trusses about 6 ft. deep and 42 ft long over all are simple Howe trusses made with single unspliced top and bottom chord timbers, which were brought into position with great difficulty on account of their length and the necessity of introducing them through the attics, for there was no way by which they could be raised directly without cutting or destroying portions of the elaborate ceiling. These timbers and other material were carried in through one end of the L-shaped extension for the Sunday school room. They were turned with considerable difficulty and it required very careful handling to get them into place, particularly those for the truss farthest from the entrance, which had to be carried across the dome and which involved cutting many of the members of the old roof and setting temporary bracing in their places. During this work the dome was not protected except by narrow platforms laid on the lower chords of the roof trusses to provide footing for the workmen.

The purlin trusses resemble the main trusses except that their dimensions and materials are somewhat smaller. The ridge truss is supported about 5 ft. clear of the main truss by two pairs of vertical angles, which are bolted across both rafter and purlin trusses and have connections for them in their opposite flanges. The eaves purlins in the planes of the side walls of the skylight frame have their lower chords seated directly on those of the main trusses and are connected to them by four vertical angles like those for the middle purlins. The intermediate purlins all have their lower chords seated directly on the top chords of the main trusses and support the rafters by short wooden columns in the planes of the latter.

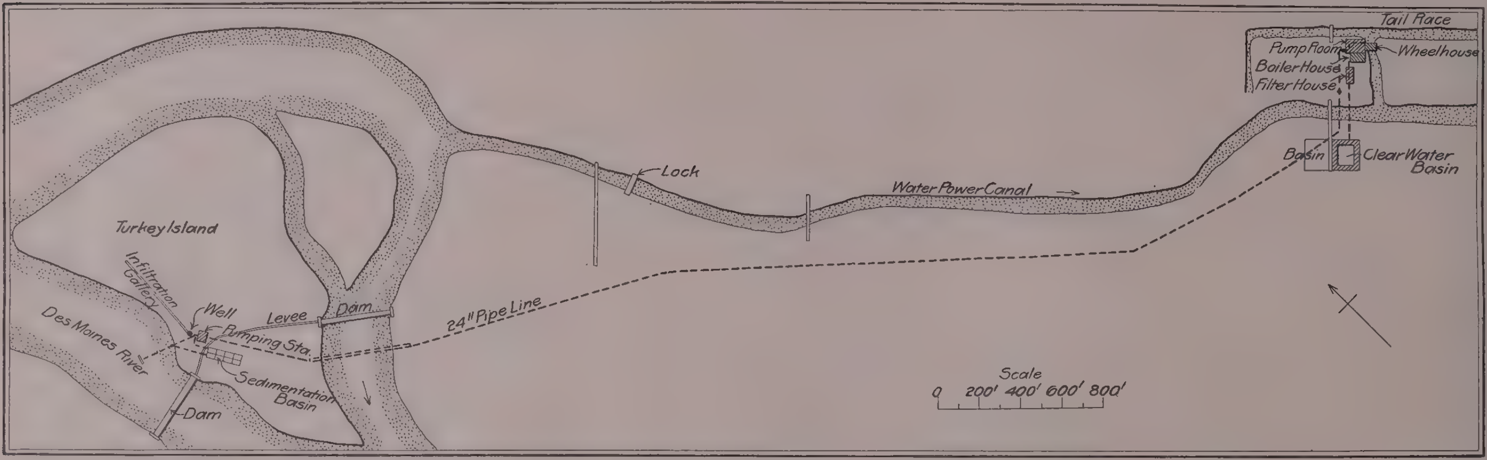


Reconstructed Roof over Church Auditorium.

After the new construction was completed all of the old work not retained in the new structure, together with the old skylight, was removed and the former obstructed attics were transformed into well-lighted spaces with a few lines of solid roof members forming a neat and strong structure. The old construction was so closely connected to the ornamental work that it was at first impossible to judge of its actual condition and strength, and grave doubts were entertained whether it would be possible to replace and reinforce the old members without injury to the decorations. This was, however, accomplished successfully in the manner described and the work was completed in about three months. Very little evidence of it was at any time perceptible in the auditorium and no damage whatever was done to the dome or other portions of the ceiling or to any of the decorations, the old shells being replaced around the new columns and connected without leaving any scars or trace of their removal. Messrs. John Thatcher & Son, Brooklyn, were the contractors and the work was executed under the personal supervision of the architects.

The Reconstruction of the Ottumwa, Ia., Water Works.

A new pumping station has recently been completed for the water-works system of Ottumwa, Ia., which, together with improvements that have been made to other parts of the system in the last two years and additional betterments that are to be carried out in the next two years, will provide an adequate and satisfactory supply for all purposes. Ottumwa has a population of 22,000 and is on the Des Moines River about 80 miles from the mouth of that stream in the Mississippi River. The first water plant in Ottumwa, built in 1880, was owned and operated under a franchise by a private company. This franchise expired in 1898, but was extended to 1902. During the extension period of the franchise, plans were made and the contract awarded for the construction of a municipal plant, but the city was enjoined by the Federal courts from starting the work. A new franchise was awarded to Underwood & Slingluff, of New York, in December, 1903, and the reconstruction of the existing plant was commenced, as required in the franchise, in the spring of 1904. The water-works station is on a power canal about 1.5 miles from the Des Moines River and its water supply was formerly drawn from this canal. At the upper end of the canal where it joins the river an island with an area of about 50 acres, called Turkey Island, divides the river into two channels. A short distance downstream from the head of the canal, a dam is built across both of these river channels, with a levee connecting the adjacent ends of the dams, the levee and dams being arranged so as to divert the water into the power canal.



General Plan of the Water Works System at Ottumwa, Ia.

The old pumping station and its equipment had deteriorated badly and although 6 gravity Jewell mechanical filters were installed in a building adjacent to the pumping station, and between the latter and a clear-water basin on the opposite side of the power canal, the filter capacity was insufficient and the water was not considered satisfactory for a domestic supply at all times. The new franchise was granted with a provision that within two years after it went into effect a new station building, with sufficient equipment for proper operation of the water-works system, should be erected; a 24-in. pipe line be laid to Turkey Island, and a number of improvements carried out on the island in order that a suitable supply of water might be secured there.

It was expected that an ample supply of good water could be obtained by sinking a well on the island and building an infiltration gallery connected with this well. After a brick-lined circular wall, 20 ft. in diameter and 25 ft. deep, had been sunk, and an infiltration gallery, 7x8 ft. in cross-section and 250 ft. long had been built, it became evident that only a partial supply was obtainable in this manner, so an 18-in. intake pipe was laid out into the river to supplement the supply obtained from the gallery.

An electrically-driven pumping station, containing two De Laval centrifugal pumps, each driven by a De Laval continuous-current 120-ampere 500-volt motor, was built on the island. These units operate at a 1,000 r.p.m. The pumps each have a capacity of 5,000,000 gal. per 24 hr. and force water against a head of 44 lb. through the 24-in. main leading to the main pumping station. On account of the variation of the water level in the river, the pumps are set in a steel tank 18 ft. square and 15 ft. deep. The top of this tank is above high-water mark and the pumps are placed so that in case the dam should break and the head in the river be reduced they would still have suction. The tank is built on and attached to a grillage of 16-in. I-beams, which project 6 ft. on all four sides. A brick wall 6 ft. thick is built on these beams to overcome the buoyancy of the tank and to form the footing for a small brick station building erected over it. The suction of both pumps is connected with a header, through which water may be drawn from the well connected with the infiltration gallery, the river, a sedimentation basin, or all of them.

The original dams were overflow, rock-filled, timber-crib structures, about 8 ft. high, which had been built for many years and were more or less impaired. The dam in the west channel was removed and rebuilt, most of the flow in that channel being diverted to the channel on the other side of the island by a rock and brush coffer dam. Substantial masonry abutments were built at each end of both dams, the two dams with the levee between them forming a diverting weir 1400 ft. long.

The new pumping station building was erected on the site of the old station, the latter being torn down as the new work progressed and after enough new machinery had been installed to furnish the city with water. The main part of the new building is a 67x90-ft. pump room, 20 ft. high, with a 50x63-ft. boiler house and fuel storage room in the rear. The building is all erected on timber piles driven 14 ft. to bed-rock. An ashlar masonry footing is built over the piles to the high-water level and above that the walls inside and out are of pressed brick. The building has a red tile roof made of roofing tile manufactured by the Ludowici Roofing Tile Co., the roof being carried by a structural-steel truss frame. The floor in the pump room is vitrified tile and the inside wall of that room is lined with white enamel brick to 6 ft. above the floor.

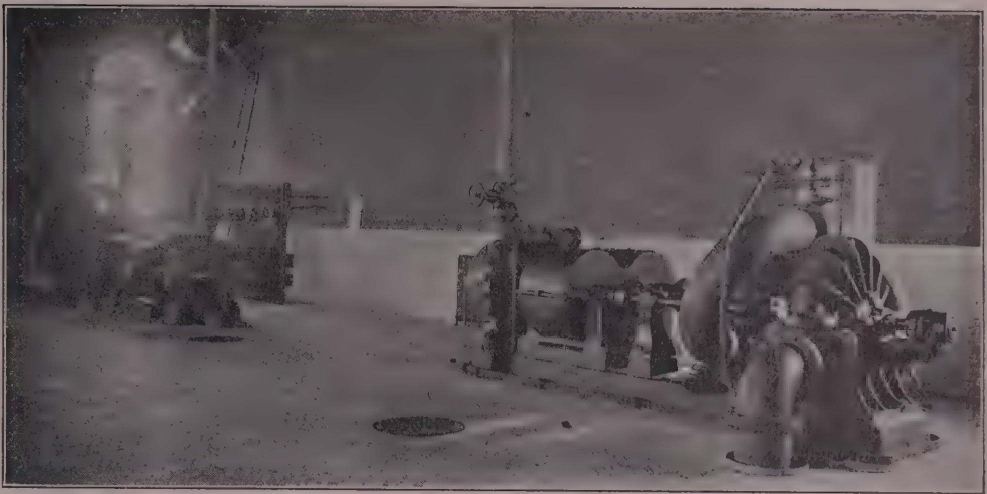
The power of the pumping station is both water and steam, the water power being furnished by the canal. A wheel house containing five American turbine water wheels operating under a head of 7.5 ft., is placed on one side of the pump room. These turbines furnish all the power necessary to run the plant during the greater part of the year. There are two Flanders horizontal compound duplex pumps in the station, one of 2,000,000 and the other of 3,000,000-gal. capacity, both being driven by water power. A 125-h.-p. Allis-Chalmers Corliss engine is connected with the shaft from the turbines which drive these pumps, so the latter can be operated by water or steam power, or by both. There is also a 5,000,000-gal. De Laval centrifugal pump driven by a De Laval steam turbine, the unit operating at 900 r.p.m. Steam power is supplied by four 72-in. x 18-ft. fire-tube boilers built by the Bass Foundry & Machine Co., of Fort Wayne, Ind. The boilers are supported by I-beams and columns and set with Dutch ovens. Their furnaces are served by a 125-ft. radial brick stack, built by the Alphons Custodis Chimney Construction Co.

The city is built on two levels, one just above high water in the river, on which the business and factory buildings and a portion of the residences are located, and a higher level, about 180 ft. above that, on which most of the more recently built residences are located. The low-level district is supplied with water by gravity under a head of 210 ft. from a distributing reservoir to which the pumps in the main pumping station deliver. The high-level district is supplied by a 1,250,000-gal. De Laval centrifugal pump, driven by a De Laval continuous-current 80-ampere 500-volt motor, in a small brick building near the reservoir. This unit runs at 1,475 r.p.m., and the pump operates against a head of 210 ft.

Two 6-ft. stand pipes, each 56 ft. high, are placed on the 24-in. main from the intake pumping station to the main station, one at each station, to regulate the flow in the pipe line and to supply sufficient head to operate the filters. From the stand pipe at the main station a connection is made with the suction well, with the filters and also direct connection to the pumps. When the water needs filtration, it passes from the 24-in. pipe line through the filters and thence to the well. When the water is of proper quality to be used without filtration, the flow is direct to the pumps, the pump suction then being under a head of 44 ft. The pumps in the main station operate against a head of about 210 ft. and elevate the water to the 2,000,000-gal. distributing reservoir.

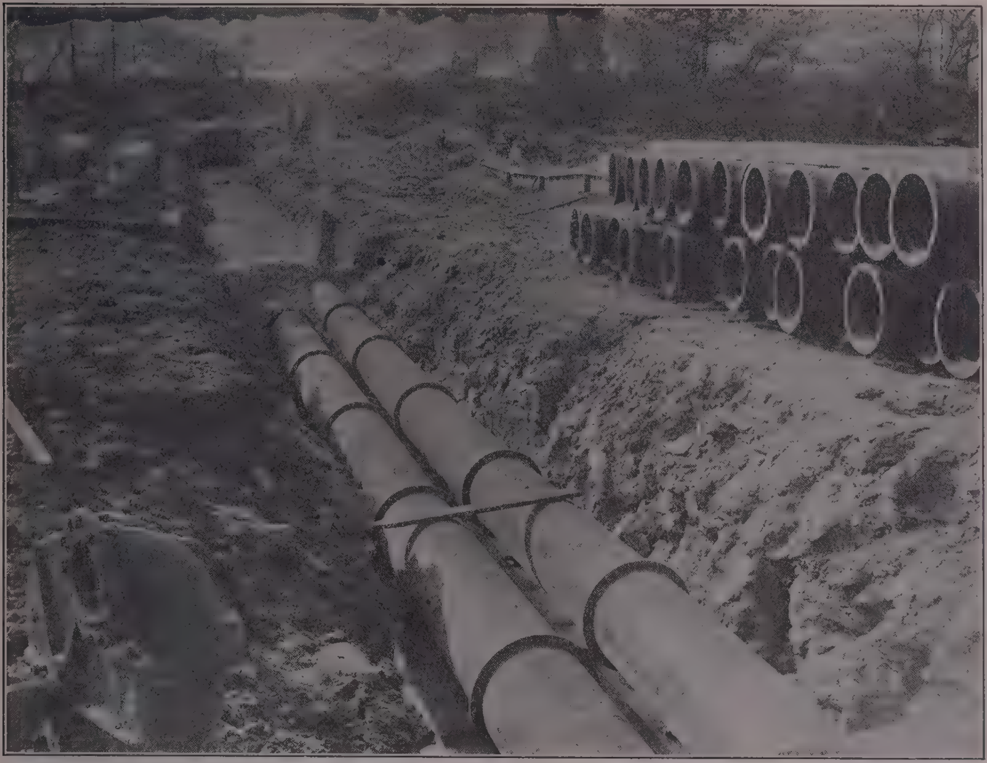
The main pumping station also contains a General Electric 250-kw., 500-volt, direct-current generator, driven by water power, and a generator of the same size and capacity built by the De Laval Steam Turbine Co. and driven by a steam turbine built by that company. Part of the current generated is transmitted to Turkey Island and used to operate the motor-driven pumps in the station there. The remainder is used to operate the motor-driven pump in the auxiliary station at the reservoir which supplies the high service district, and for lighting the various buildings.

No special engineering difficulties were encountered in any of the construction. Two lines of 24-in. cast-iron pipe, 600 ft. long, are laid under the channel of the river where the pipe line from the intake station to the main station crosses the stream. A coffer dam was built exposing half of the river bed at a time, while the work was being carried on, a moderate amount of pumping being required to keep the trench dry. The two pipes were laid side by side in a channel 5 to 6 ft. deep blasted in the solid rock bed of the river; the channel was then filled with concrete to the level of the surface of the rock.



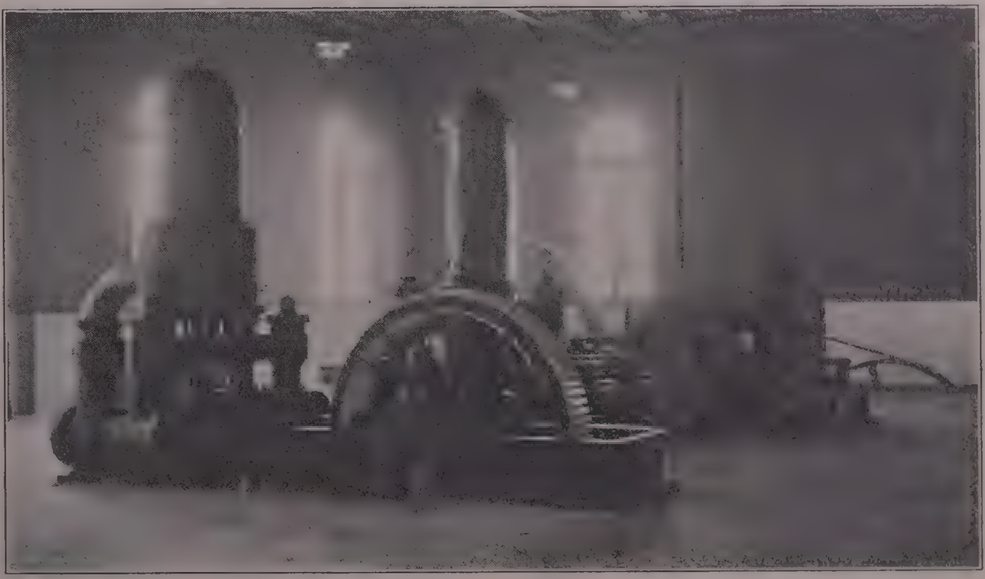
Pump and Generator Units, Both with Steam Turbines.

The betterments remaining to be made under the provisions of the franchise include a sedimentation basin at the intake pumping station, a clear-water basin beside the existing one, 5 miles of distribution mains and extensive repairs to the distribution reservoir. The sedimentation basin will be divided in compartments and will be covered. A suction pipe will connect with the last compartment near the top and the water will be pumped through the 24-in. pipe line where it will pass through the filter and thence to the clear-water basin.



Laying Two 24-Inch Pipes under the Des Moines River.

The improvements are all being made, according to the franchise, under the direction of the city engineer, acting for the city, who also audits the accounts of expenditures on the improvements and reports them to the city council. A fixed price was placed on the old work at the time the improvements were commenced and to this valuation is added the cost of work done at the end of the two and four-year periods from the time the franchise was granted. The total valuation at the end of either period is what the city may pay and acquire the entire system. At the end of 10 or 25 years after the franchise was granted the city may, if it has not already done so, also buy the works at an appraised valuation to be made at the time of purchase by a commission of disinterested engineers.



The Two Flanders Pumps.

The improvements have been made under the immediate supervision of Mr. James Winans, of Toledo, Ohio, who is manager and superintendent of the water works for the water company. Mr. C. R. Allen, city engineer, represented the city. The information from which this article has been prepared and the illustrations in it were furnished by Mr. Allen. The 24-in. riveted steel pipe line and the two standpipes connected with it were made by the Bass Foundry & Machine Co. The Flanders pumps were built by the Ottumwa Iron Works. The main pumping station was erected by the L. T. Crisman Co., of Ottumwa.

THE TIE CONSUMPTION on the two leading Canadian railways was discussed at the recent Canadian Forestry Convention. Chief Engineer Joseph Hobson of the Grand Trunk system stated that during the seven-year period, 1896-1904, the average annual number of ties used was 2,102,600, equivalent to about 63,000,000 ft. B. M. Of about 2,200,000 cedar ties bought last year, 1,500,000 were obtained from the United States. Cedar is the favorite wood for ties on this road because of its great immunity from decay, the present annual tie consumption being only about a half of what it was before cedar was used. The annual consumption of ties on the Canadian Pacific Ry. was stated by Mr. L. O. Armstrong at the same convention as 5,000,000, equivalent to about 140,000,000 ft. B. M. White oak, tamarack, fir and hemlock are used mainly.

The Erection of the Mercantile Marine Building, London.

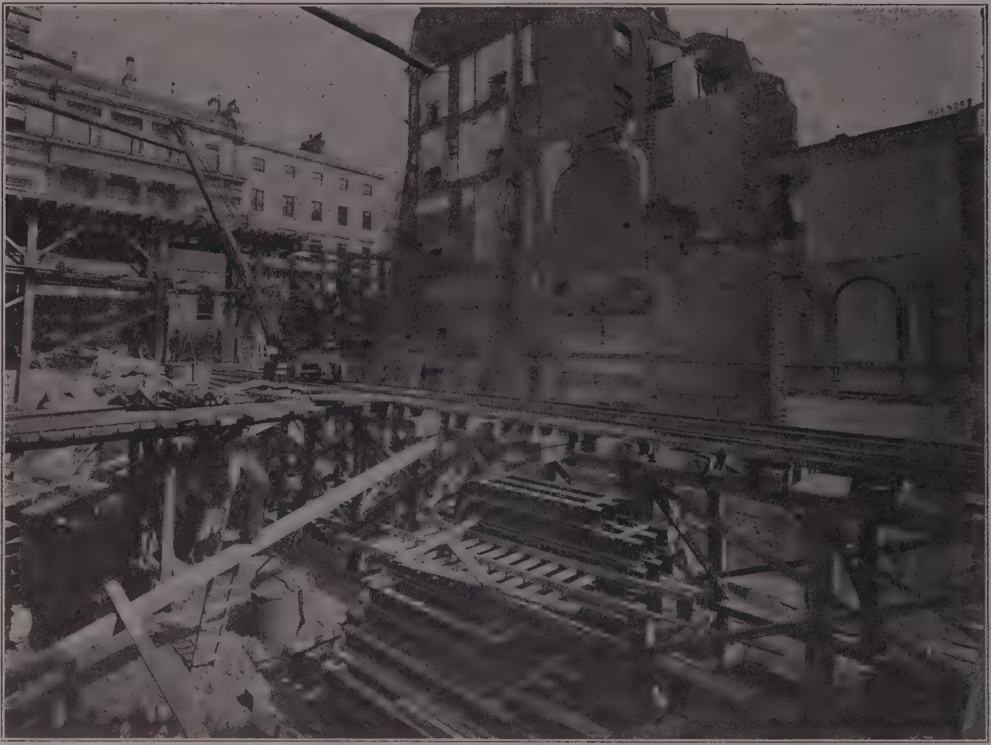
The new six-story office building of the Mercantile Marine Co., Cockspur, St., London, has a steel roof and floors supported on the exterior walls and on interior steel columns. Its site was previously occupied by a five-story stock exchange building called Waterloo House, which was erected in 1821. Its walls were of the best quality of brick laid in lime mortar, were faced with stone work and were found in good condition when the building was demolished by a house-wrecking contractor. Piping, lavatory fittings and woodwork were first removed. Then holes about 6 ft. square were cut in the same vertical line through the floors and the debris was thrown down through them to the first floor and basement and removed by wagons. Screens were put up on the outside to prevent debris from falling to the street.

The party wall of an adjacent building was 106 ft. long and 60 ft. high, and, being in poor condition with its foundation only 1 ft. below the basement floor level of the new building, was underpinned in successive sections about 6 ft. long. Corresponding portions of the old wall were taken out in alternate lengths to a height of about 4 ft., and after the necessary excavations had been made under them, concrete footings 2 ft. thick were laid there and new brick piers were built up and wedged against the old brickwork in the usual manner. The walls had sufficient strength to carry across these openings and no needle beams were used.

The face of the wall was braced with inclined shores in sets of four each. Each set was located in a vertical plane perpendicular to the face of the wall and the shores in lengths of 8 or 10 ft. were spaced about 1 ft. apart and had square ends bearing on inclined caps and sills, with their ends gained into the brickwork. Each story of shores had independent caps and sills, and a third packing piece was inserted between the cap and sill at each story so as to virtually make a deep transverse girder separating the shores and thoroughly distributing the stresses between them. The two sets of shores were tied together by horizontal timbers engaging both shores and sills.

The street sides of the lot were enclosed by a tight board fence outside which was built a heavy bridge 15 ft. high over the sidewalk platform which was temporarily raised 2 ft. to provide for rebuilding the old vaults. The upper platform or bridge was enclosed by a tight board fence over 6 ft. high and was used for storing stone hoisted from wagons in the street by means of two derricks provided there for that purpose.

The cellar floor was about 13 ft. below street level and about 1 ft. above ground-water level. The soil over about one-half the area was hard blue mud, all of it being considered suitable to receive the new foundations. These were built in pits excavated about 2 ft. below the old floor, and requiring the removal of about 350 cu. yds. of spoil, taken out with pick and shovel except in two cases where engine foundations recently built required blasting. The spoil was shoveled into two ½-yd., one ¾-yd., and two 1-yd. side dump steel skips which were handled by 3,000-lb. and 6,000-lb. locomotive derricks with fixed booms and turntables, which could hoist and swing the loads, transport them, and deliver them to wagons in the street. These derricks were of typical English construction and were very rapid and convenient in their operation. Another work on which the same class of locomotive derricks was used by the same contractors was the New Cotton Exchange in Liverpool, and one of the accompanying photographs shows them at work on this structure. Each of the derricks on the London work had a boom about 25 ft. long commanding a circle about 25 ft. in diameter and traveled at street level on tracks supported on a heavy timber falsework erected before the excavation was commenced. Pairs of 6x12-in. longitudinal sills were laid on the cellar floor about 6 or 8 ft. apart and on them were erected 8x8-in. vertical posts about 10 ft. apart longitudinally and braced by transverse and diagonal struts. They carried directly on their upper ends two lines of 6x6-in. longitudinal stringers which received the 8x8-in. cross ties about 3 ft. apart. Longitudinal planks 3-in. thick were carried on the cross ties and to them were spiked the rails. The trestle was braced to the foundation in several places. When the old cellar floor was excavated under the bottom sills the latter served to carry the track over the pit until shores or cribbing could be placed under it extending it to the bottom of the excavation. The sides of the excavation were retained by the old vault walls which were left undisturbed until the new building had attained a height of about four stories, when they were removed and new vaults constructed without sheet piling.



Falsework for Excavation and Erection of Mercantile Marine Building, London.

The footings for the exterior walls were 18 in. of Portland cement concrete underneath a grillage consisting of a lower tier of 12-in. I-beams and an upper tier of 8-in. I-beams. The spaces between the piers were filled with concrete and the brickwork 6 ft. wide was started on the beams and carried up to the basement level where the stone facing commenced. The walls were waterproofed by 1 in. of rock asphalt applied in two coats with a trowel. The concrete floor was waterproofed with a ½-in coat of hot rock asphalt, sanded. The foundations of the interior columns were of similar construction, receiving a cast iron pedestal 12 in. high on top of the grillage beams, their footings being carried down about 5 ft. below the finished basement floor.

Concrete was made with Hilton Anderson cement purchased from the Associated Portland Cement Co., and was mixed by hand and turned three times. Brick, sand, cement and other materials were not stored in any amount at the building, but were delivered daily by carts from which they were unloaded on the sidewalk and taken in wheelbarrows to inclines where they were chuted to the cellar or to elevators of the hod-hoist type driven by a Lidgerwood hoisting engine.

The stone work was handled entirely by derricks. The steel was delivered from the shops in London by carts and was immediately hoisted by a 3-ton stiff-leg derrick carried on top of the framework as it advanced. Whenever possible the steel was erected by the derrick as hoisted; in other cases it was stacked up on the floorbeams around the derrick until it could be assembled. The steelwork was handled by two 3-ton stiff-leg derricks with steel masts, very long steel booms, and wooden sills and stiff legs. Each of them was operated by a hoisting engine in the cellar driven by a 15-h.-p. Westinghouse electric motor and was capable of lifting 2 tons with a two-part tackle.

When the derricks were lifted to the successive floors the boom of each was first unshipped, hoisted and laid across the beams of the upper tier. The stiff legs were then disconnected and the mast was hoisted by a tackle suspended from shearlegs erected on top of the steel work. The foot block was then hoisted and placed under the mast which remained guyed in position until the sills and stiff legs were hoisted with shear legs and connected to the mast. The boom was then connected to the mast, the tackles were rigged and the derrick was again in service after an interruption of about 12 hours for its removal and re-erection.

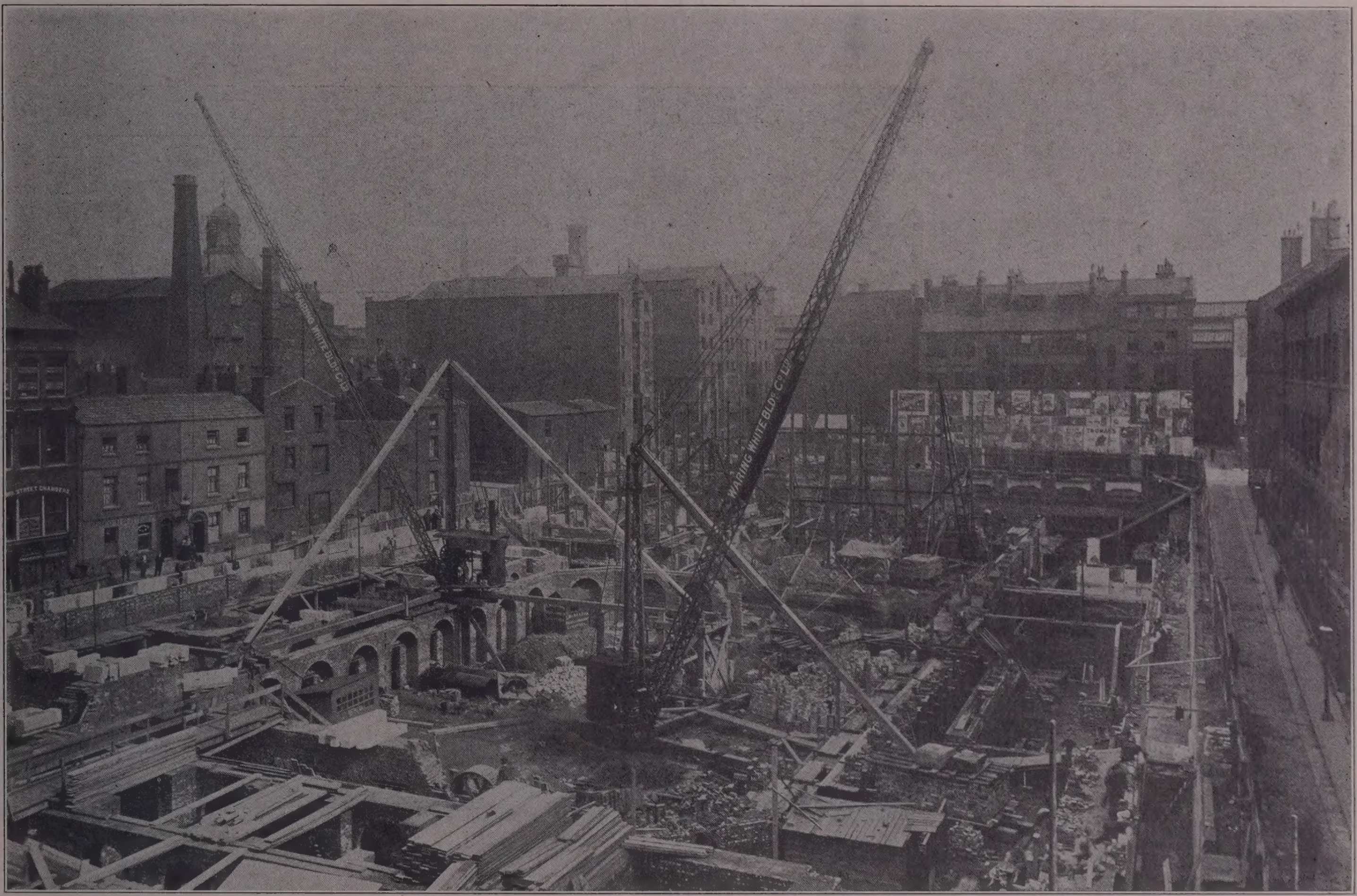
The building contains about 300 tons of steel, the heaviest piece weighing about 3 tons, and the greatest amount erected in one week being 20 tons. The steel was so accurately manufactured that no field reaming was required. All connections were bolted, no field rivets being used. The verticality of the columns was tested by a plumb-bob suspended about 6 in. beyond the face of the column at the top. The columns were braced by diagonal struts from their tops which had jack screws at their feet to provide necessary adjustment during erection.

The exterior walls were built from a mason's scaffold carried up to the roof from the top of the sidewalk bridge. It was made with vertical posts about 10 ft. apart, each of which consisted of fir poles about 30 ft. long and from 5½ to 6½ in. in diameter at the butt. At the foot of the scaffold these poles were used in pairs but in the upper part they were used singly, thus enabling them to be built upwards with staggered joints and convenient splices. They were spliced, fastened together, and connected to the round horizontal pieces which carried the platform boards entirely by rope lashings, no spikes or bolts being used because of their injury to the timber, their liability to rust, and the necessity of shifting their position. The lashings were made with best hemp cords about 13 ft. long wound around both pieces. To tighten them a turn is taken around a hammer handle, which is used as a lever with the head as a fulcrum against the pole. By this method considerable tension is put in the cord and when the lashing is completed the loose end is put under the tightest turn of the wrap. The poles are thus connected without injury and are generally used for several successive buildings. The scaffold poles are found very convenient for erection purposes, and being light and stiff are very readily lashed together and erected to form shear legs for hoisting light loads.

The principal plant included one 3-ton stiff-leg derrick with a 65-ft. boom built by Butters Bros., Glasgow, one 3-ton A-frame derrick and two 2-ton hand power A-frame derricks built by Jackson & Sons, London; two 15-h.-p., 200-volt Westinghouse electric hoisting motors and one single drum Lidgerwood hoisting engine and five hand-purchase crabs. The force employed averaged about 150 men, some of whom worked at night on the construction of the new sidewalk vaults on account of the scarcity of room in the basement and on account of the fact that the elevator was employed all day in removing the excavated material. In some instances, also, the steel erectors and cut stone masons worked until 8 or 9 o'clock at night, and toward the last the plasterers worked until 10 p. m. in order to finish the building at the required time.

Operations were commenced tearing down the old building on June 1, 1904, wrecking was completed on Sept. 13, steel erection was commenced Sept. 12 and finished Jan. 15, 1905, progress being delayed on account of the necessity of building the walls at the same rate so as to carry the outer ends of the floorbeams. Interior construction was commenced Jan. 13, under a temporary roof at the second floor which enabled plastering to be done in the first story. The main roof was finished March 8, and the building was ready for occupation May 1, 1905.

Mr. Henry Tanner, Jr., was the architect. Mr. Sven Bylander was the consulting engineer and designed the steelwork. The Waring White Building Co., Ltd., was the general contractor and Mr. F. W. Nicholson was the superintendent of erection. The National Fire-Proofing Co., New York, was the sub-contractor for the partitions, the Yale & Towne Co., New York, was the sub-contractor for the hardware, the Danville Asbestic Plastering Co., was the sub-contractor for the plastering, and the Columbia Fire-Proofing Co. was the contractor for the fire-proof floors.



The Locomotive Cranes with Long Booms used in Building the Liverpool Cotton Exchange.

The New Pumping Engine of 25,000,000-gal. capacity, recently installed at the Pettaconset station of the Providence water-works by the Allis-Chalmers Co., developed a duty of 179,476,000 ft.-lb. per 1,000 lb. of dry steam on its trial run. The indicated power was 844.3 h.-p.

Underpinning Old Walls with Steel Columns.

The erection in New York of a tall office building on the block bounded by Cedar, West and Albany Sts., made necessary the excavation of trenches alongside the walls of adjacent buildings to a depth of 18 ft. below the curb. These trenches were excavated around piles, several rows of which had been driven to support grillages and girders for the wall columns. The soil here consists of a fill over soft black river mud extending to bedrock, a distance of 45 to 50 ft. below the curb. It is saturated with water up to a level only about 4 ft. below the curb.

On one side of the lot is a tenement house and a warehouse, separated by a small two-story building which is supported on timber piles. The latter building was in such condition that its stability was not jeopardized. The other two buildings, each about 70 ft. high, had walls of brick laid in lime mortar and supported on footings laid in the mud about 8 ft. below curb level. The wall of the tenement building contained a large number of ducts which considerably weakened it; it was built of rather poor materials and had a thickness of 20 in. at the bottom, where it was supported directly on a grillage of transverse sawed timber 12 in. thick resting on a pair of hewed white pine 12x20-in. longitudinal sills laid flat. The warehouse wall had foundations of poor rubble masonry supported on a similar footing and was weakened by a number of door and window openings which had been cut through it and subsequently filled up. The footing timber, being well below the ground-water level, had been perfectly preserved; some of the sticks were as much as 62 ft. long. Each of the walls was about 70 ft. long and 70 ft. high. Some of the floors of the warehouse were heavily loaded.

Underpinning operations were begun by cutting in the walls recesses which were 10 to 15 in. high, 3 ft. long and 15 to 26 ins. deep. Reaction girders were set in the recesses and grouted in. The recesses were cut without entering the buildings or disturbing the tenants. Each of the reaction girders for the tenement house wall consisted of three 8-in. I-beams 3 ft. long fastened together by a horizontal tie bolt through the neutral axis near either end. The spaces between their webs were filled with concrete; the solid, compound beams thus formed were placed in the wall cuts or recesses, leaving a space of about 2 in. between their upper flanges and the brick work; this space was filled with 2x1 in. bars on edge driven in transverse to the wall about 1 in. apart in the clear and grouted.

On the center line of each reaction beam a vertical recess about 14 in. wide and 15 in. deep was cut from the beams to the bottom of the footing, and in it were seated two 3-ft. sections of 10-in. pipe concentric with one 6-ft. section of 9-in. pipe placed vertically. On top of the double tube thus formed was placed a heavy cast iron plate. A 60-ton Norton ball-bearing screw-jack was mounted on the plate and operated to force the double tube 3 ft. into the ground. The jack was then removed and the upper 3-ft. section of 10-in. pipe was replaced by a section 6 ft. long and a 3-ft. section of 9-in. pipe was placed on top of the 6-ft. section first set. This arrangement brought the upper ends of the double pipe to a convenient height above the bottom of the footing and provided staggered joints 3 ft. apart. The ends of the pipes had been accurately cut in a machine shop to square bearings. The annular space between the two pipes was of uniform width throughout. Uniformity was preserved by means of separators attached to the sections of inner tubing. The jack was replaced on top of the pipes, and they were forced 3 ft. further into the ground, when 3-ft. and 6-ft. sections were added to the outer and inner pipes and the process continued until the pipes were forced to bedrock. When the friction became too great, the screw-jack was replaced by a Watson-Stillman 100-ton hydraulic jack.

The sinking was facilitated by the use of an interior hydraulic jet at about 60 lb. pressure, which was operated through a vertical slot in the special upper section of the pipe used for jacking. The jet was delivered through a heavy chisel-shaped nozzle which could be used to break or dislodge obstacles. After the pipe was sunk to rock, the mud in it was washed out by the jet. When the inflow of ground water was not too strong, the pipe was pumped out by a special pump lowered into it. The pipe was then filled with ordinary concrete shoveled in at the top. In some cases where the water could not be removed from the pipe, the latter was filled with grout which displaced the water. The grout was mixed in a horizontal, closed cylinder and was forced out under air pressure, at the same time that it was thoroughly agitated by a paddle-wheel turned by hand and having its axis passing through stuffing boxes in the ends of the grout tank. The grout flowed from the end of a pipe at the bottom of the pile or column.

After the pipe had been sunk to bedrock and filled, a well-greased upper section, cut to the required length, was put in position with its top about 4½ in. below the lower flanges of the reaction beam. The face of the vertical recess in the wall was then enclosed by form boards and the space in and around the greased pipe was filled with concrete. Finally the pipe was capped with a 15x13¾x15-in. planed cast-iron plate on which were seated six planed steel wedges 19 in. long, 2½ in. wide, 3/16-in. thick at the point and tapered 1:60. On top of these wedges was placed a 15x15-in. planed cast-iron plate beveled to correspond and 2 in. in maximum thickness. After all of the eleven pipes had thus been sunk under the wall of the tenement house, the wedges between the cast-iron pipes were simultaneously driven forcing the upper plates against the bottom flanges of the reaction beams and gradually lifting the wall uniformly until its weight was entirely carried by the pipe-columns, as was proved by the appearance of a horizontal hair-crack at the elevation of the under side of the reaction beam. The projecting ends of the wedges were cut off with hack-saws and the underpinning was completed. The load on each of the columns is about 50 tons.

The underpinning for the warehouse building was substantially the same as for the tenement house, except that the loads being heavier the dimensions of the pipes and beams were greater. The pipe-columns were capped with 17x17-in. cast iron plates separated by wedges 3 in. wide. The reaction beams in this case were 12 in. deep and when bolted together had a combined width of 17 in. The ten underpinning columns were made of 11 and 12-in. diameter pipes and were proportioned for a working load of about 70 tons each.

Underpinning an Old Brick Wall With Double Pipe Columns.

The above described work was designed and executed by Clark & Co., New York, under the general direction of the architect, Mr. Cass Gilbert, Mr. Gunwald Aus, consulting engineer. After the completion of this work John Monks & Sons, contractors for the foundations, excavated a trench alongside the underpinned walls and in it drove the foundation piles for the new building. The trench was at first excavated only a few feet below the surface of the ground; after the piles were driven sheeting was put down on the inside of the trench and the excavation was carried to the total depth of about 18 ft. below the curb. The earth was not removed at this time between and beyond the piles of the outer row. These piles were braced back to the waling pieces on the inside of the trench to enable them to resist the pressure from the earth under the old building. Later sheeting was driven outside this row of piles, as nearly as possible in the face of the walls, and the excavation was completed to the bottom of the trench. Eventually the sheeting was removed in sections and the space behind it faced with concrete to serve as a retaining wall for the earth under the cellar floors of adjacent buildings.

The Sudan Railway.

The Sudan Railway, recently formally opened by Lord Cromer, is by no means a new project. So long ago as when Col. Henry G. Prout, now general manager of the Union Switch & Signal Co., was governor of the Equatorial Provinces of Egypt, he had surveys made for a railway line in this country and the project was discussed many times after that. During the Mahdi's rebellion the military need for the line became so evident that its construction was undertaken as soon as possible. Work began in 1903 at Suakin, on the Red Sea, but it has since been decided to abandon that port as a terminus for a new one known as Port Sudan. The line reaches the Atbara River about 20 miles above its junction with the Nile, and follows its banks to the Khartum-Wady Halfa military line. Its total length is 332 miles, the maximum grade is 1 per cent., and the sharpest curve is 5 deg. Track work did not begin until the summer of 1904, and the construction of the 332 miles of road, much of it across a desert and all of it under severe climatic obstacles, was a work of which the engineers have reason to be proud. The completion of the line makes the shipping distance from Khartum to the seaboard a little more than a fourth of the former distance by way of railway and river boats to Alexandria. While the country traversed by the line is of little importance it is expected that the trade of the Equatorial Provinces will be greatly developed by the shipping facilities afforded by the railway.

A Ganz Steam Motor Car is under trial by Florida East Coast Ry. It has a 50-h.-p. motor upon the forward truck, steam being supplied by two small boilers upon the platform.

Book Notes.

Mr. Dwight Goddard has prepared, under the title of "Eminent Engineers," a 280-page book containing brief biographies of Benjamin Franklin, John Fitch, Nathan Read, Oliver Evans, Robert Fulton, John Stevens, Robert L. Stevens, Eli Whitney, Thomas Blanchard, Elias Howe, John Ericsson, Peter Cooper, George H. Corliss, Alexander L. Holley, William R. Jones, James B. Eads, Richard Arkwright, Thomas Newcomen, James Watt, Matthew Boulton, William Murdock, William Symington, Richard Trevithick, Henry Maudsley, George Stephenson, I. K. Brunel, James Nasmyth, Alfred Krupp, Charles Babbage, Sir Joseph Whitworth, Sir Henry Bessemer and Sir William Siemens. These short articles bear the mark of greater technical than historical accuracy, and exception may well be taken to the inclusion in a list of engineers of a number of men who were either expert mechanics or inventors whose ideas had to be developed by others before they became of practical value, even if they had merit, which was not always the case. The information concerning the men mentioned is presented in an interesting manner and the biographies are accompanied by a number of illustrations that are of even more value than the text. Anyone who has endeavored to gather together portraits of pioneers in any industry or profession will appreciate the labor that must have been spent on securing the illustrations for this work. (New York, Derry-Collard Co., $1.50.)

The appearance of a fourth edition in three volumes of the "Hilfsbuch für Dampfmaschinen-Techniker," by Prof. Josef Hrabak, of the Royal Mining Academy at Pribram, affords an opportunity for calling the attention of readers of German to one of the most unique contributions ever made to the technical literature of steam engine design. The eminent author began the preparation of the first edition more than a quarter century ago, his purpose being to furnish the designers of steam engines with a set of tables containing the leading data for an engine of any size and type. The theoretical treatment was to be checked by the results of tests, so that the tables could be used to save a large amount of preliminary calculation. The principal data sought in such tables are the power and the steam consumption. It is manifest that tables based on piston speeds directly would be too voluminous to be practicable, so the author chose a new unit on which to arrange them, capacity per meter piston speed. The main tables give both the indicated and delivered horsepower per meter piston speed at a number of points cut-off, and are arranged in three series. The first includes the data for engines of usual sizes, operated non-condensing and condensing and provided with different valve gears. The second series is for very large engines and the third for engines using high steam pressures, 7 atmospheres and over. To accomplish his purpose the author was compelled to make a special analysis of engines with a link gear, from which all other gear systems, so far as the distribution of steam is concerned, could be deduced as special cases. These subjects and many more are discussed in the second volume of the book, but the first volume contains only the tables and general directions for their use. The arrangement of the data concerning steam consumption is also a novel one devised by the author to avoid over-elaboration. For this purpose he separated the steam losses into those connected with condensation and those associated with leakage. The estimation of the steam consumption and losses for any engine of any type is reduced in this way by means of the tables to a matter of the most elementary calculation. In the many years that have elapsed since the first edition of the book appeared there have been great changes in steam engine design and these have been followed by additions to the tables and a recasting of the theoretical portion of the book, in which the methods followed in the preparation of the tables are explained in detail. The new edition that has just appeared also has a third volume devoted to engines using superheated steam and blowing engines. The marked favor with which the earlier editions of the book have been received by German engineers, who have a very rich steam engineering literature from which to choose, is the best criticism that can be made of these volumes. (Berlin, Julius Springer; cloth, three volumes, large octavo, 20 marks.)

One of the most important books for civil engineers that has appeared in a long time is Mr. Robert E. Horton's "Weir Experiments, Coefficients and Formulas," issued by the U. S. Geological Survey in its series of Water Supply and Irrigation Papers. It is a thorough sifting of all reliable data on weirs and weir formulas, with a large amount of new information of the highest value, based on the experiments made for the Survey at the Cornell hydraulic laboratory. The book is not only useful for the information it affords concerning the ways of making such measurements but also for the light it throws on the corrections to be made to old measurements in order that they may be rendered of maximum usefulness. The introduction to the book gives a general statement of the terms used in weir measurements and the various formulas and coefficients employed in computing the discharge over weirs from the results of the measurements. The theory of such measurements is then explained and the effect of the velocity of approach is pointed out. After clearing the way in this manner for detailed investigations, the author takes up the thin-edge weir and discusses all the work done with it from the earliest experiments of Castel, Poncelet and Lesbres, Boileau, and the engineers on the Public Works Department of India. Then the experiments and formulas of James B. Francis, Fteley and Stearns, Bazin, Hamilton Smith, Parmley and Cippolletti are investigated and a large amount of practical information concerning the subject is given. Mention should be made particularly of the comparison of various corrections for velocity of approach, and the occasional explanations of the reasons for the differences in the various formulas and their probable accuracy when extended beyond the limits of the experimental data on which they are based. The chapter on the requirements and accuracy of weir gaugings which follows ought to be made a portion of the reading of every civil engineering student. The succeeding chapter on the results of experiments on various forms of weir cross-sections is the longest in the book and in some respects of the most importance. It gives admirable summaries of the experimental work of Bazin, the Deep Waterways Board, John R. Freeman, the U. S. Geological Survey, Blackwell, Fteley and Stearns, and others, and brings together in convenient form all the data that most engineers will ever require. Mr. Horton has gone to great trouble in some cases to recompute the data in cases where subsequent investigations showed the necessity of revising earlier tables. For this reason the data are in better shape for direct consultation than in the original papers containing them. The discussion of submerged weirs which follows, summarizes the reliable information on the subject and will be found particularly useful on account of the comparison that is drawn between different formulas. This chapter is followed by one on weir discharge under varying heads. The book concludes with an admirable collection of tables for the calculation of the discharge over weirs. These give the head due to various velocities, the percentage of increase in discharge by various rates of velocity of approach, the discharge over a thin-edge weir by the Francis formula when the depths of water run up to 10 ft., three-halves powers of numbers from 0 to 1.49, the flow over broad-crest weirs with stable nappe, and the backwater caused by a dam or weir. The book can be obtained by applying to members of Congress.

Trussed Roofs and Roof Trusses. By F. E. Kidder. New York, Wm. T. Comstock; cloth, 8vo, 297 pp., $3.00.

Some years ago the late F. E. Kidder, author of the well-known "Architects' and Builders' Pocket Book," contributed a series of articles to two architectural journals on the subject of trussed roofs. There were unusually successful, judging from the comments they called out from architects in many parts of the country, and the author accordingly determined to elaborate them in a volume of his "Building Construction and Superintendence" series, the most elaborate work yet undertaken in this country on the general subject of architectural construction. In this new book Mr. Kidder's aim was to describe nearly all types of roof construction used in such buildings as architects design, to point out the advantages of the different types of wooden and steel trusses for different spans and building requirements, and to explain the method of computing the loads, drawing the stress diagrams, and proportioning the members and details. Special pains were taken to make the mechanical principles as plain as possible and to describe the method of obtaining the stresses so that any intelligent person could apply them without violating any scientific principle. He had in mind the needs of architectural draftsmen and builders rather than those of the educated engineer, and accordingly gave more space to the descriptions of wooden trusses and the common types of steel trusses than to intricate engineering detailing, the object being to make the book of practical value to the greatest number of people. The Engineering Record was frequently consulted by the author during the preparation of the volume, and it can bear witness to the thoroughness with which he investigated the design of the many details of steel roofs taken from this journal for his book; while it was in preparation he was a thorough critic of this portion of the journal's contents and his comments proved of no little assistance in the preparation of many articles.

The first chapter of the book discusses the mechanical principles involved in the design of wooden trusses and describes their various types. The next chapter covers the same ground with steel trusses. Chapter three explains the methods of laying out trussed roofs and describes the methods of constructing simple types. Chapter four is on open timber roofs and church roofs, chapter five on vaulted and domed ceilings and octagonal and domed roofs, chapter six on the roofs of coliseums, armories, trainsheds and exposition buildings, chapter seven on the computation of the purlin and truss loads and the supporting forces, and chapter eight on stress diagrams and vertical loads.

One of the most valuable aids to the architect is a knowledge of what has been done in different lines of building construction, and for this reason a great many examples of existing trusses and of trussed roofs are illustrated.

These examples were selected as guides to the designer as to the shape of the truss, the section of the members, the detailing of the joints and the manner of bracing laterally and to the posts and walls. The author pointed out that it is seldom that a truss can be safely copied outright, but after the stresses have been computed, the illustrations in this book will be found of much assistance in deciding on the manner of building the truss, proportioning the joints and bracing the roof. This richness of illustrative material coupled with the author's well-known clearness in explaining the computation of stresses ensure the book a wide circulation.

Letters to the Editor.

A National Organization of Contractors.

Sir: Considerable interest has been stimulated among contractors by the criticisms of the form of government contracts contained in the recent articles on the law of this subject by the Messrs. King, which have appeared in your paper. It has been suggested that the one-sided provisions of government contracts might be eliminated from them if united action were taken by the leading contractors. There is no doubt that some of the most prominent contractors prefer not to take government work on account of the presence in the government contracts of so many provisions enlarging the discretion of the officers in charge of the work. In other instances the contractors feel it necessary to insure themselves against loss by increasing their bids over the amount for which the work could be done, if the requirements of the contract were made certain and less were left to discretion. Some allowance for this risk must necessarily be made.

One contractor who has had more than thirty years' experience in contracting for the United States, the States and municipal corporations, expressed himself to the writer as follows:

"For years I have been firmly convinced that matters never can be properly adjusted, as to contracts and contractors, until the whole system of contract letting from the U. S. Government down is properly revised by a commission, in which the contractors are properly represented and their suggestions embodied in such legislation as may be necessary. I have at present in this office stacks of specifications covering a wide range of work, that are filled with absurdities and incongruities, and yet contractors must make their contracts under them or go out of business. Most lines of business have some methods of organizations whereby their interests are in some degree protected; the contractors have absolutely none and the consequence is they are afflicted with many burdens, grievous to be borne and await some Moses to lead them and organize them that they may go out and possess the land. I have had in mind for years an organization covering the whole country organized by States, and chapters, if you please, to which every contractor should be willing to contribute his dues for the benefit of the order. This will take time and money of course, and a leader."

A leading engineer who has served the government for over thirty years and during that time has spent millions of the government's money without ever having had a lawsuit over any of the contracts executed by him, recently stated to the writer his rule in drawing contracts. He said that he uniformly aimed to make the obligations of the contractor absolutely definite and to leave just as little room as possible for the exercise of discretionary power. His view was, that in the end the government saved money by this over what it would cost to do work where the contractor had to bid upon the chance of unexpected exactions through the exercise of the engineer's discretion.

Contractor.

Street Bounds.

Sir: Two of your readers having taken exceptions to some of the statements made in the writer's communication in your issue of March 3, it is presumably up to him now to explain, to use a slang phrase. Your correspondent from the city of Lynn, Mass., cannot see why the writer should state, "that a curve for the line of a street cannot be laid down on the ground." The answer is simply this, because it cannot be done. The writer understands, of course, how street curves are usually laid out. But no curve of any description, can be run on the ground, by setting stakes, no matter how near together they are set. They only indicate a straight line from one stake to the other, while a curve, intended to be a portion of the arc of a circle, is a line everywhere equally distant from the center. Suppose your correspondent is called upon to lay out a curved street line of 500 ft. radius over land worth $1,000 per sq. ft., every square inch worth over $7, how can this line be shown on the ground?

Your Boston correspondent, in your issue of March 10, does not approve of the corners of stone posts for marking street lines. He thinks a drill hole in the center of a monument set in the sidewalk 2 ft. from the street line a better scheme, because it would save the surveyor the trouble of making an offset to avoid obstructions along the street line. Doubtless this would be very convenient for the surveyor, but how about the public travel?

Stone monuments, set as has been the usual custom, little end down, are more or less liable to come up from year to year, the writer having in mind several instances where monuments set on the street line 20 or 30 years ago, 6 in. high are now 20 in. above the surface of the sidewalk, rather a formidable object for your correspondent to encounter on a dark night, when the street lights are out. A Massachusetts surveyor should be familiar with the laws of this State that require stone bounds to be set to mark the angles and termini of all streets by whomsoever laid out.

Again your correspondent thinks it would not be a good plan, or even possible, to lay out all streets the same width. Of course not, and all the writer said in his article of Feb. 3 was that new streets should be laid out, of uniform width from end to end. From 1861 to 1905 the writer has laid out over 50 miles of streets in the city of Haverhill and nearby localities, of all widths, from 20 to 100 ft., and experience in such work convinces him of the truth of the above opinion. Lincoln Ave., in this city, was laid out by the city authorities in 1872 100 ft. wide, and 1,600 ft. long, from its junction with Water St. easterly to the west line of the city farm, but the city government declined to contribute so much land, and they reduced the width through the city farm and other estates to 66 ft., where the junction was made through a curve about 500 ft. long, all the land being contributed by the owners of the several estates.

Washington St. was originally opened through the estate of one Jacob Ayer, in the year 1758. 33 ft. wide, and all the house lots sold off, bounded on Ayer's new road, by which name the street was known until Washington visited Haverhill in 1789, when, in honor of this, the greatest event the town had ever known, Ayer's new road, was rechristened Washington St., and is now one of the principal avenues in the city, about two miles in length, 50, 55 and 60 ft. wide, in one place 80 ft., and at the junction of High St. 140 ft. wide, all of which has been relocated from time to time, by the writer of this article, and bounded by granite monuments set to mark the exact line of the street.

Haverhill, Mass., N. Spofford.
March 24.

Reinforced Concrete.

Sir: My attention has been called to an error in my letter on reinforced concrete, published in your issue of March 17, which affects some of the results arrived at. I stated that the moment of the compressive stresses about the neutral axis equals that of the tensile stresses about the same axis, when the proper assumption is, of course, that the algebraic sum of those stresses is zero, or that the sum of the compressive stresses in the concrete equals the tension in the steel. The statement referred to occurs near the top of the third column on page 382, and the remainder of the letter should be as follows:

If we now fix the safe unit stress for the steel, we have all the necessary data for determining the position of the neutral axis, the area of the steel and the total moment of resistance.

For $A_S S_S = \Sigma C =$

$$5000\, b \int_0^{y_1} \frac{y^2 dy}{9y_1 + y} = 258.4\, b\, y_1 \qquad (1)$$

$$d = y_1 + x,\ S_S = E_S{}'_S \text{ and } 7s = x/5{,}400\, y_1.$$

$$\therefore S_S = 29{,}000{,}000x/5{,}400y_1 = 290{,}000\ (d - y_1) \div 54y_1 \qquad (2)$$

$$y_1 = 290{,}000 \div (290{,}000 + 54S_S)$$

$$x = d - y_1 = 54S_S\, d \div (290{,}000 + 54S_S) \qquad (3)$$

$$A_S = 258.4\, by_1 \div S_S = (54 \times 258.4)\ by_1^2 \div (290{,}000\ (d - y_1) \qquad (4)$$

If we assume $S_S = 16{,}000$ lb., we have:

$y_1 = 0.25d$ and $x = 0.75d$.

$M_C = 10.625\ bd^2$.

$A_S = 0.0041\ bd$ (percentage $= 0.41$).

M (total) $= M_C + A_S S_S\, x = 59.1\ bd^2$, we have if we make $S_S = 8{,}000$ lb.,

$y_1 = 0.4d,$

$x = 0.6d,$

$M_C = 27.2\ bd^2,$

$A_S = .012831bd$ (percentage $= 1.2831$)

M (total) $= 89.2\ bd^2$.

Hence, we see that in a rectangular beam of given dimensions, we may increase its resisting moment 1½ times by making the stress in the steel 8,000 lb. instead of 16,000, but at the same time we increase the amount of steel threefold.

If K is the cost per foot of the beam, and M/K is the ratio of moment to cost $= k$, then $k = F\,(y_1)/f\,(y_1)$, and by placing $dk/dy_1 = 0$ and solving for y_1 we obtain a value for the latter which would make k a maximum, and this is the location of the neutral axis for the most economical section.

Assuming the relative values of 35 cents per cu. ft. for the concrete and 2 cents per lb. for the steel, we find:

$y_1 = 0.42d$, and $x = 0.58d$,

$S_S = 7{,}416$ lb.,

$A_S = .01464\ bd$ (percentage $= 1.464$),

$M_C = 30\ bd^2$,

M (total) $= 93\ bd^2$.

The stress in the steel is, therefore, less than one-half that considered safe for medium steel, and the uselessness of employing material having a higher tensile strength than the ordinary structural product is clearly shown.

New York, W. M. Farrar.
March 22.

A Good Road Campaign promising important results has been opened in West Virginia. Every county is interested and a convention to discuss the subject met in Wheeling on March 14 and 15.